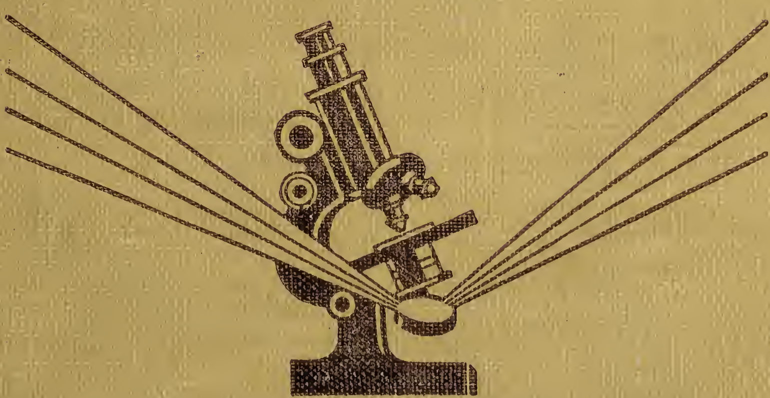
modern SCIENCE

IN OUR DAILY LIFE



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IN OUR DAILY LIFE

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CHARLES E. DULL PAUL B. MANN
PHILIP G. JOHNSON

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Preface

In Book 1 of this *Modern Science* series, the authors introduced the pupil to his environment. He met water in its various forms. He learned that air is a substance. He explored the earth and learned something of the plants and animals that live upon the earth.

In Book 2 of this series, the pupil himself is the central figure. The science that he studies is the science of those parts of his environment which most closely affect his daily life. In studying about water, the pupil will be particularly concerned with the methods which communities (including his community) and individuals (including himself) use to secure an ample supply of healthful water.

He will see that both air and water affect the climate in any locality. He will study the influence which weather and climate exert upon the individual. He will come to recognize, in his study of sound, that air forms the most important medium for communication. He will study the subject of heat energy, discovering how heat energy is transmitted to the places where it is needed, and how it is prevented from escaping from our houses and from our bodies in cold weather. He will be introduced to consumer science in the chapter about clothing; and in the chapter on the methods of keeping clothing clean, he will find practical projects for putting his new knowledge to work.

Just as Robinson Crusoe looked over the island upon which he was shipwrecked, so the pupil in Book 1 studied his surroundings. Just as Robinson Crusoe then began to bring food ashore from the wreck, and to study his personal needs, so the science pupil in this book is led to study his own needs and to learn how he can keep his body in good health. The human

body is a self-operating machine, and there are many strange and wonderful facts which can be learned about that machine. *Modern Science in Our Daily Life* does more than point out how fearfully and wonderfully man is made. It includes enough physiology to give meaning and emphasis to the rules for health which many pupils may already have memorized but not understood or applied.

There are several reasons for including in *Modern Science in Our Daily Life* a considerable amount of science dealing with the human body: (*a*) this study shapes desirable attitudes toward health in a critical period in the nation's history, when any individual's health and endurance are likely to be drastically tested; (*b*) many schools do not find time later to give courses concerned with the human body; (*c*) the subject of biology is too full to afford much time for human biology; (*d*) some pupils leave school before they reach the ninth grade; (*e*) a knowledge of the functions of the human body is necessary as a background for studying the effects of narcotics and alcohol, which must be taught in every state; (*f*) a knowledge of the structure of the human body is necessary to an intelligent use of first aid, which itself has become an urgently needed skill. The final unit in this book offers the pupil the principles of "safety first" and of first aid.

The language of this book is simple. As in Book 1, scientific terms are italicized when they are introduced; they are fully explained and, if they are difficult to pronounce, the pronunciations are indicated by diacritical marks and respelling. Challenging questions lead into each chapter. The diagrams and half-tone illustrations are integrated with the text by references. A glossary at the end of the book is at the pupil's command. The readings suggested in the bibliography, and the activities which close each chapter emphasize the theme of this book, which is, "mens sana in corpore sano."

The Authors

Charles E. Dull is supervisor of science for the Junior and Senior High Schools of Newark, New Jersey, and head of the Science Department in the West Side High School. He is the author of *Modern Chemistry, Modern Physics,* and *Safety First — And Last.*

Paul B. Mann is head of the Biology Department in the Evander Childs High School in New York City, and was formerly supervisor of science in the Senior High Schools in New York City. He is co-author of *Biology, Biology for Beginners,* and *Out of Doors — A Guide to Nature.*

Philip G. Johnson, editorial consultant for the *Modern Science* series, is assistant professor of education at Cornell University, and supervisor of student teachers in science in co-operation with the Ithaca Public Schools.

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Man Needs Pure Water

Does your mind take things as it finds them? Or does it inquire? Do you wonder sometimes about the importance of the things that you need in your daily life? Have you ever thought how inescapable our need is for a supply of pure water?

You have already learned what water is, and something about its properties. You know why it rains. Now you will learn why we cannot live without reasonably pure water.

Imagine for a minute that you are going to build a house in the country. How will you plan to get water? If there is no spring on your land, you will need to dig a well, deep enough so that the water will be free from the impurities found in water near the surface of the earth. Unless you can strike gushing water, you will have to install a pump to raise the water. If the water contains harmful bacteria, will it be safe to bathe in? How is water useful in getting rid of wastes?

In Unit 1 you will find out how men have solved some of the problems connected with their water supply. You will

find out how they have overcome the tremendous difficulties of furnishing water for a city of seven million people. You will find out also why water must be purified and what methods man uses to purify it so that it will serve his needs, in winter and in summer, without harming him.

Think about these!

1. A man buys a farm in the country. There is no well on his property. What things must he think of in deciding where to locate his well?

2. In one skyscraper in New York City there is office space for 10,000 or more workers. The building is a block square. Even if wells were dug underneath the building, do you think they would supply enough water for the people in the building? What do you think " the city water problem " is?

3. Bacteria may be present in drinking water. How is it possible to destroy them? Do you know any methods now used to purify drinking water?

Words for this chapter

Sediment. Settlings; dregs; material deposited by water.

Contaminated. Soiled; stained; defiled; polluted.

Fission (fĭsh′ŭn). Reproduction of a cell by splitting into two parts.

Epidemic (ĕp′ĭ·dĕm′ĭk). Applied to a disease which spreads widely and attacks many persons at the same time.

Aqueduct (ăk′wė·dŭkt). A channel or pipe for conveying water.

Aeration (ā′ẽr·ā′shŭn). The process of exposing to the chemical action of the air.

Algae (ăl′jē), plural. One type of flowerless plant.

Septic. Causing or tending to promote decay.

Decomposed (dē′kŏm·pōzd′). Separated into the elements of which it is made up; decayed.

CHAPTER 1 ———— UNIT 1

Why Is Clean Water Important for Our Health?

1. **Why must man have water?** In our earlier study of science, we learned that man can live only a few days without water. His muscles contain a great quantity of water. His digestive juices are composed largely of water. The six quarts (about twelve pounds) of blood present in the body of an average-sized man consist chiefly of water. Our nerves are made up largely of water, and many of the foods which we eat are at least 50 per cent water. Man needs water to flush away the waste substances that would otherwise accumulate in the body. *Perspiration* is useful in keeping the body cool in summer and in carrying away impurities. It contains a high per cent of water.

2. **What is pure water?** We are accustomed to say that water is *pure* if it does not contain any foreign matter that makes it unfit to drink. It is better to speak of such water as *wholesome* water. Water may contain considerable foreign matter and yet be fit to drink. Its wholesomeness depends upon the kind of impurities that are present in the

water. For example, some kinds of mineral matter dissolved in water do not make it unfit to drink. You would not care to drink water, however, which had compounds of lead, zinc, copper, or arsenic (är′sḗ·nĭk) dissolved in it. Some clear, sparkling water is actually dangerous to drink, and water which is not entirely free from color may be harmless. We call water *impure* if it contains impurities that are dangerous to health. We call water *wholesome* if the impurities it contains are not injurious to health.

3. **How does water carry impurities?** Have you looked at a running stream just after a heavy rain? If you have, you know that it is muddy and full of *sediment.* Fill a pail with such water and let it stand for a few hours. You find that the particles of sand, clay, and fine gravel have settled to the bottom of the pail. Running water will pick up particles of clay and sand and carry them considerable distances. When the water stands, most of the material which it had carried in *suspension,* or undissolved, sinks to the bottom, because it is denser than the water itself and cannot float. Swift streams can transport more sediment, and larger particles of sediment, than those streams which flow slowly. [See Fig. 1–1.]

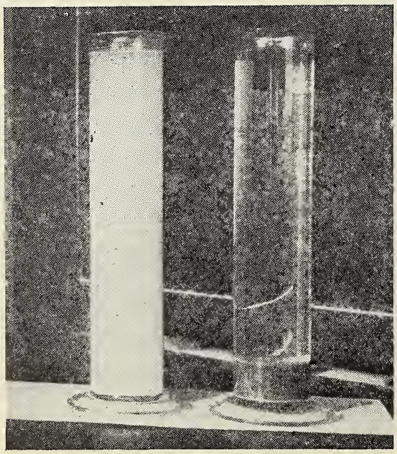


FIG. 1–1. Very small particles settle slowly, even though they may be denser than water. A bulky mass, formed by the use of chemicals, may carry the tiny particles down with it. When that happens, the water will clear quickly. (*Photo by Wettlin*)

As water flows through soil or trickles over rocks, it dissolves some mineral matter. Most natural water, except rain water, contains some mineral matter in *solution*, or dissolved. The water may appear clear and colorless, because the particles of mineral matter dissolved in the water are so tiny that one cannot see them even with the aid of a microscope. We may try the following experiment to show that water contains mineral matter in solution. Filter the water to strain out any sediment that might be present. Then place about a tablespoonful of the water on a watch glass; let it evaporate entirely, by resting the glass on the rim of the beaker half full of boiling water. The mineral matter will be left on the glass and can be easily detected. You can see, therefore, that *water may carry impurities in suspension or in solution.* [See Fig. 1–2.]

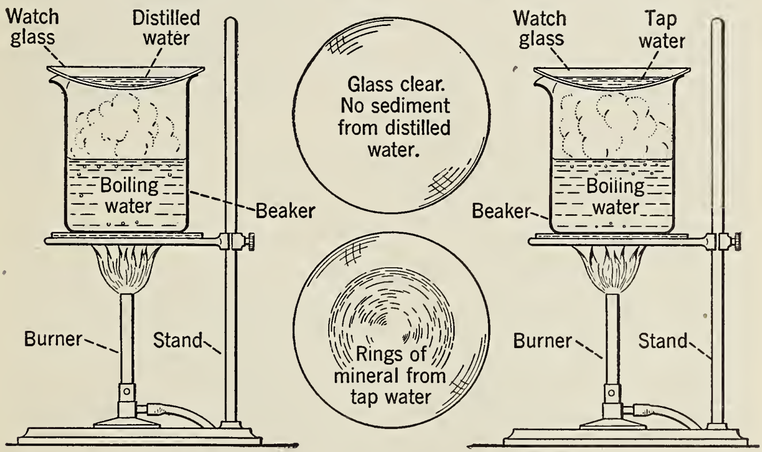


FIG. 1–2. Distilled water evaporates and leaves little or no residue. Most drinking water contains mineral matter in solution.

4. What kinds of impurities are found in water? The impurities found in water are of two kinds: (*a*) those that come from rocks or soils, and that are known as *mineral matter*, and (*b*) those that come from plants or animals, and that are called *organic matter.*

As a rule, the mineral matter present in water is not likely to be injurious. The particles of fine sand and clay carried in suspension are not poisonous; neither are the compounds of *calcium* (kăl′sĭ·ŭm) and *magnesium* (măg·nē′shĭ·ŭm)—two soft metals found in combination with other elements. Of course one should not drink water containing much sediment. In rather rare cases, poisonous minerals are found dissolved in water.

Not all organic impurities found in water are harmful. [See Fig. 1–3.] Bread, for example, if placed in water, does not immediately make the water unfit to drink. But when the bread begins to decay, it will then impart to the water a disagreeable odor and a bad taste.

Many organic impurities, however, are harmful. Twigs, parts of plants, and leaves sometimes get into our water supply. As they decay, they make the water unfit to drink. *Bacteria* which cause disease are likely to get into water. They need organic foods in order to grow and multiply. Bread, scraps of garbage, and other types of organic matter may furnish them with food.

Water *contaminated* with plant *refuse* (rĕf′ūs), or rubbish, of any kind is unfit to drink. If it is contaminated with animal wastes or refuse, it is dangerous. Wells must be kept free from surface water which may have flowed from stables or barnyards. Sewage may get into rivers, lakes, or even water reservoirs.

5. What are bacteria? Possibly van Leeuwenhoek (lā′vĕn·ho͝ok′), a Dutchman who spent much of his time making microscopes and peering through them, was the first man to see bacteria. They are so small that they must be magnified greatly to be seen at all. Tiny as they are, they feed, grow, and multiply somewhat like other plants.

In order to thrive, bacteria must have moisture. They may be found on dry surfaces, but they do not grow and multiply unless moisture is present. Some of them will grow in rather low temperatures, and a few of them may for a

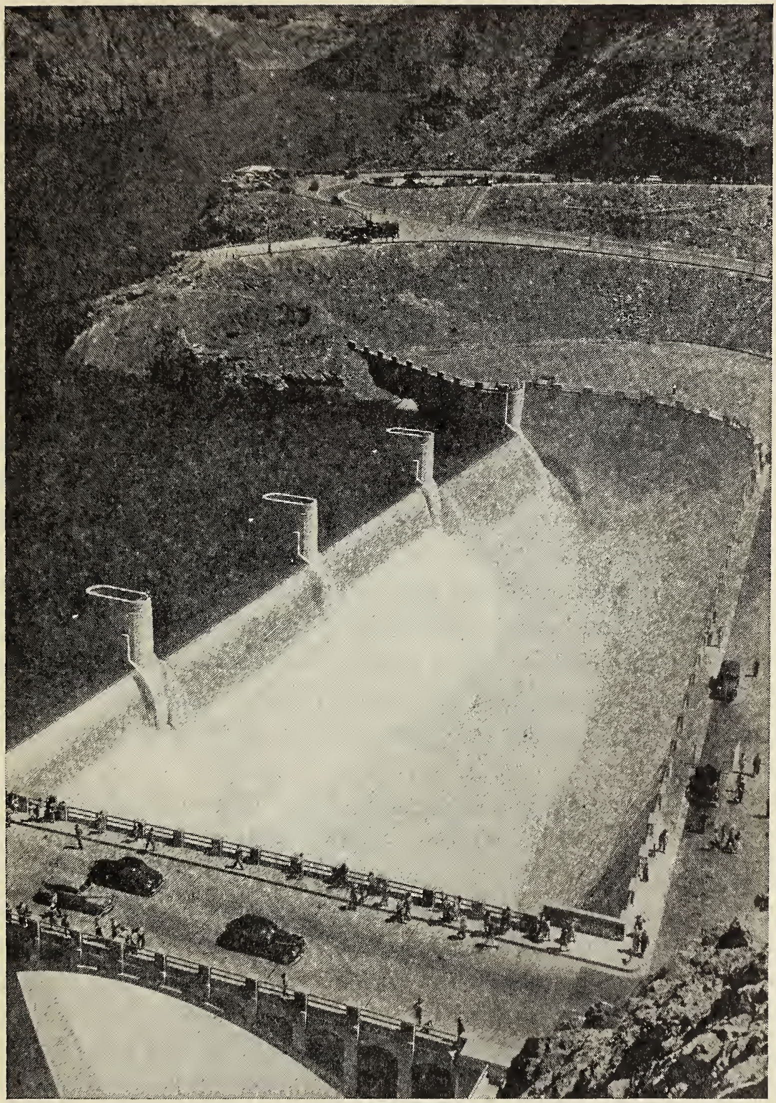


FIG. 1–3. How might organic impurities find their way into the water of a dam such as Boulder Dam, which is shown here? (*Courtesy U. S. Department of the Interior, Bureau of Reclamation*)

short time survive at the temperature of boiling water. As a rule, however, they thrive best at a temperature of from 50° F. to 100° F.

If bacteria are to grow and multiply, they must have some kind of food. They grow well in broth, gelatine, milk, mashed potatoes, cheese, meat, and many other foodstuffs. It seems almost like a contradiction to say that *bacteria multiply by simple division.* Suppose that you could split a dollar bill into two pieces and that by the end of a half hour, each piece would have grown to the size of the original dollar and would look like it. Then you could split each dollar into two parts again and have four dollars by the end of the next half hour. If you could keep on *dividing* your money at that rate for ten hours, you would have *multiplied it* enough so you would be a millionaire. Bacteria grow and multiply in that manner, by a process called *fission.* One bacterium splits to form two bacteria; they grow to about the size of the original bacterium. Then the two bacteria split to make four; the four grow and split to make eight; the eight make sixteen; and so on until there are millions of them by the end of twenty-four hours, if the conditions have been favorable.

6. What shape are bacteria? The different kinds of bacteria are of various shapes. Some of them are round, or *spherical* (sfĕr′ĭ·kăl); they are called *cocci* (kŏk′sī). Some have a tendency to cling together to make long strings like necklaces of pearls or beads. [See Fig. 1–4.] Some bacteria are like tiny cylinders in shape. They are called *bacilli* (bȧ·sĭl′ī). The *spirillum* (spī·rĭl′ŭm) type of bacteria is shown in Figure 1–4. These bacteria are shaped like a corkscrew. Observe, too, the rather peculiar shape of the bacteria which cause *tetanus* (tĕt′ȧ·nŭs), or lockjaw. Some bacteria have tiny threadlike fibers at one end or at both ends.

7. Are any bacteria friends to man? Dr. Conn of Wesleyan University used to give an interesting lecture entitled "Our Friend the Microbe." We are so accustomed to blame

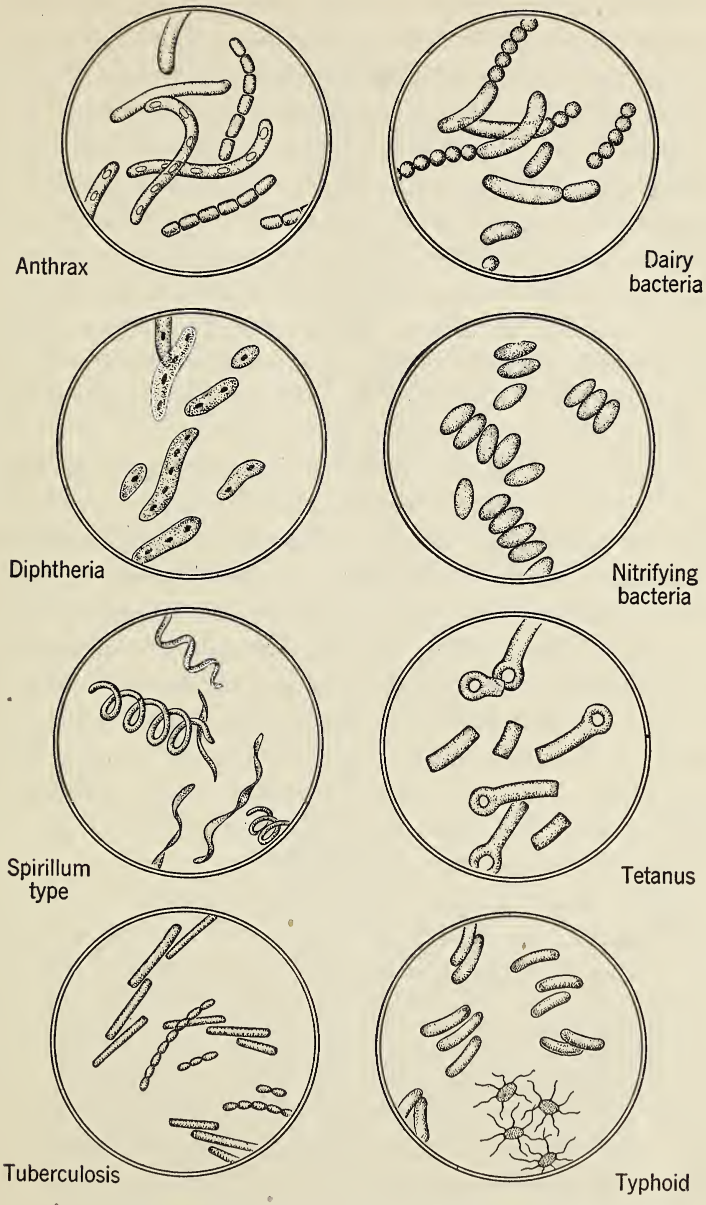


FIG. 1–4. Some bacteria are man's enemies, but others, like nitrifying bacteria, are necessary friends.

bacteria for all our ills that we may forget that most kinds of bacteria are man's friends. Some bring about decay and thus help to get rid of refuse. *Nitrifying* bacteria grow on the roots of peas, beans, and clover and make fertilizers which are needed for the proper growth of plants. Some bacteria cause milk to sour and thus make it possible for us to have cheese and other products of sour milk. Other bacteria give flavor to butter and to cheese. Bacteria aid in converting hides into leather. Some bacteria help to separate the linen fibers from the flax plant. Some friendly bacteria help to destroy other bacteria which are unfriendly to man. In fact, about 70 per cent of all the known kinds of bacteria are either beneficial to man, or entirely harmless.

8. **Bacteria may be man's worst enemies.** Although many types of bacteria are beneficial to man, yet some of them are his worst enemies. They are called the disease-producing bacteria. It is believed that there are about 70 kinds of bacteria that may cause diseases in man. There are several that produce the various types of pneumonia. Bacteria also cause such diseases as lockjaw, typhoid fever, anthrax, cholera (kŏl′ẽr·ȧ), bubonic (bū̆·bŏn′ĭk) plague, diphtheria (dĭf·thē̦r′ĭ·ȧ), tuberculosis, and several others. The world owes a great debt to Louis Pasteur, who learned that bacteria cause disease and also learned how to prevent certain diseases and how to treat them.

9. **How do we get harmful bacteria from water?** About 4000 persons in the United States die each year from typhoid fever. The bacilli that cause this disease may find their way into the body of a person through water that was contaminated with sewage. If such water is used for washing milk cans, a person using the milk may contract the disease. Sanitation, vaccination, and education are controlling this disease. Although there are about 14,000 cases of typhoid fever in the United States annually, yet a typhoid *epidemic* is not so common as formerly. Not very long ago, there were 100,000 cases each year. Thousands died of typhoid fever dur-

ing the War between the States. In 1898, about 5000 who enlisted for the Spanish-American War died of typhoid fever. Only 300 were killed by Spanish bullets. In the summer encampment of soldiers in 1898, the death rate from typhoid was 897 for every 100,000 men. Have conditions improved? Of 12,801 soldiers in San Antonio, Texas, in the year 1911 there was only a single case of typhoid fever and that man got well. During the World War, in the year 1918, the death rate from typhoid fever was no more than 3.3 men per 100,000.

It seems fairly certain that cholera and some other diseases may be spread by the use of impure water. *Dysentery* (dĭs′ĕn·tĕr·ĭ) is sometimes caused by the drinking of water which contains tiny, one-celled animals called *amoebae* (*ȧ*·mē′bē).

10. Where should a well in the country be located? The man who builds his home in the country must secure clean, wholesome drinking water. If there is no near-by spring, he must dig a well. Many farmers build their houses and their barns upon a knoll (nōl), or a low hill, so that water will drain away from them. A careless farmer may dig his well

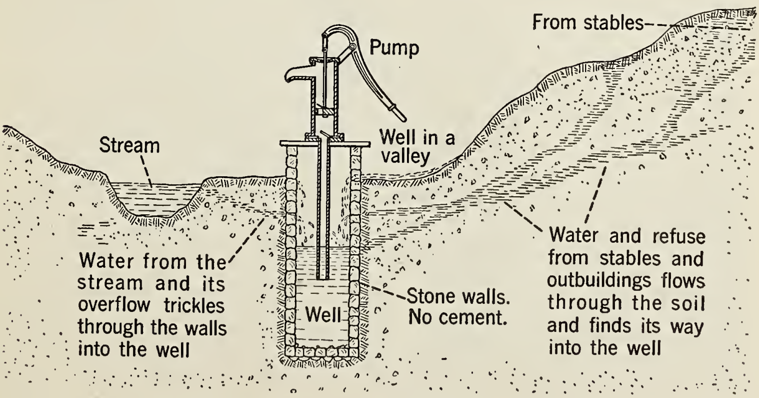


FIG. 1–5. Water may be contaminated by sewage from stables. It is easy to find water in a valley, but a well in a valley must be protected.

in a valley because he does not have to dig so deeply in order to find water. If we look at Figure 1–5, we can see why such a practice is dangerous. When heavy rains come, the water may carry sewage from outhouses and refuse from stables into such a well, either by flowing over the top of the well curbing, or through the crevices between the rocks used for making the walls of the well. A properly constructed well must be so situated that no surface water can flow into it. The rocks used in building the walls should be set in concrete in order to make the well watertight. Such walls should extend above the ground high enough to shut out surface water. The well should be covered with a cap of stone or concrete. The well itself should be dug or drilled into the earth or the bedrock deeply enough to reach below the *permanent water table.* [See Fig. 1–6.]

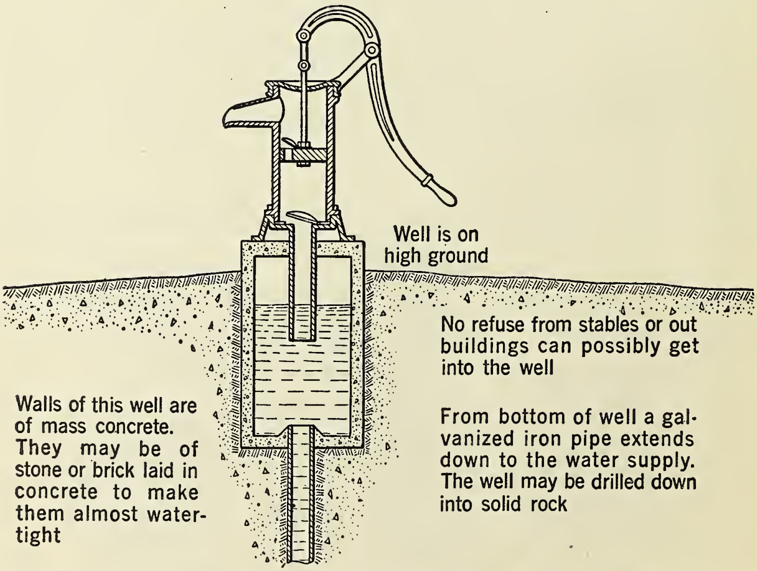
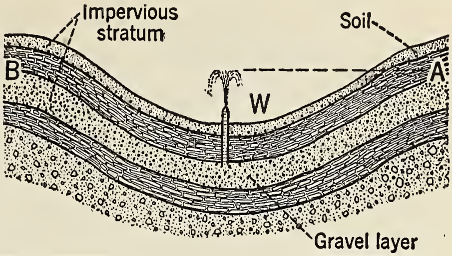


FIG. 1–6. A well on high ground is likely to be deeper than a well in a valley. The pipe at the bottom of the well extends down into rock until a layer of underground water is reached.

FIG. 1–7. Water flows downhill. The pressure of the water at A and B pushes the water from the gravel layer up through the rock to form a fountain, or a flowing well.



If the well is bored deep enough, it may reach water that will flow up through it like a fountain. Such a well must be dug down into a layer of porous rock or gravel, which lies between two layers of solid rock through which water does not pass, or through which it percolates very slowly. [See Fig. 1–7.] Water flows down between the two layers of bedrock and pushes some of the water up through the well-opening. This is called an *artesian* (är·tē′zhăn) well. [See Fig. 1–7.] It is named for the province of Artois (är′twȧ′) in France, where it was first popular.

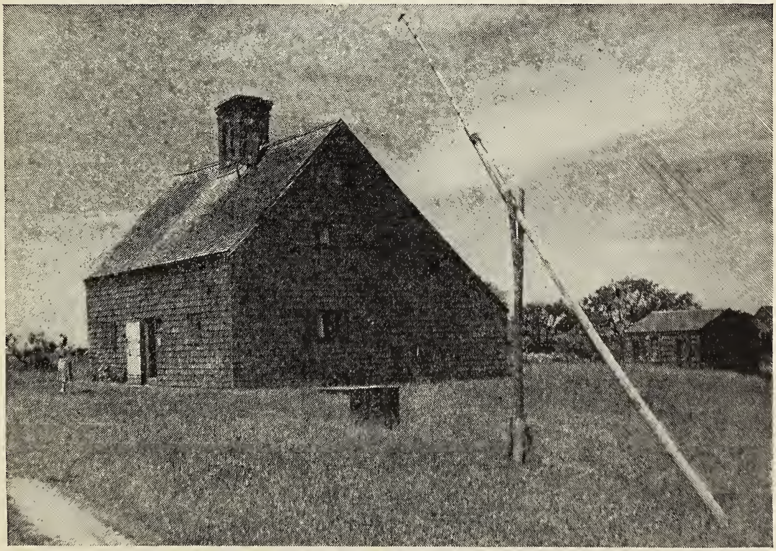


FIG. 1–8. The well sweep is still found in some localities. This well supplies water for those who live in the oldest house on Nantucket. (*Philip D. Gendreau*)

11. How can we get water from a well? In the days of "the old oaken bucket," one end of a rope was fastened to the handle of a pail or bucket. The other end was fastened to the end of a long pole which was so pivoted that it could be used as a lever. Such a well sweep is shown in Figure 1–8. Instead of a well sweep, a *windlass* might be used. One end of a rope is so fastened to the barrel of the windlass that it will unwind as the bucket is lowered into the well and then wind upon the barrel in order to lift the bucket. [See Fig. 1–9.] Windlasses are still in use today. Now, however, several types of pumps are in common use.

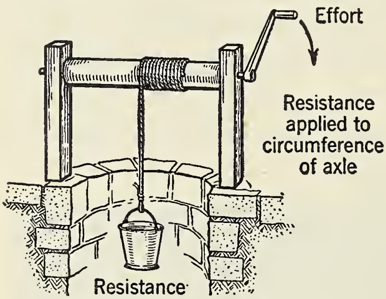
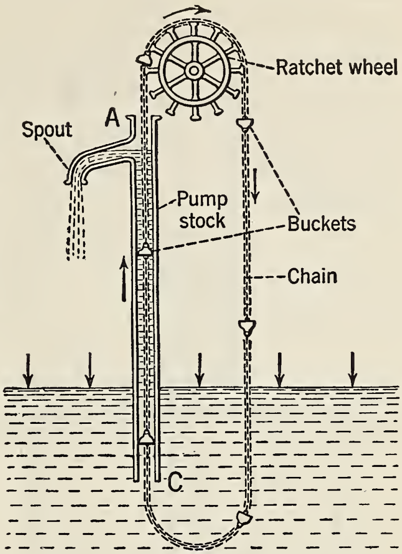


FIG. 1–9. The windlass was more often used in the days of "The Old Oaken Bucket" than it is today. One occasionally finds a windlass, however, in certain rural sections.

a) *The common chain pump.* In a pump of this kind, a tube or pipe extends downward from the spout of the pump into the water. [See Fig. 1–10.] Through this tube runs an endless chain (a chain with all its links attached to one another). One part of the chain can be pulled up through the tube by means of a wheel turned by a crank; at the same time the other portion of the chain is lowered into the water. Along the chain, a few feet apart, are solid, bell-shaped pieces of rubber, called "buckets." As a bucket moves upward through the tube, it fits so tightly that air cannot flow past it. The air above the bucket is pushed out of the tube of the pump. Thus a partial vacuum is formed below the bucket. The downward pressure of the air upon the surface of the water in the well pushes some

Fig. 1–10. One of the least expensive pumps used on the farm and for cisterns is the chain pump. Such a pump is efficient, too, when used for shallow wells. The pipe leading down into the water may be made of wood or of metal.



water up into the tube. The water is then carried upward to the spout of the pump, being partially pushed upward by the pressure of the air, and partially by the bucket which follows. Water flows out of the spout continuously as the crank is turned.

b) *The lift pump.* In this kind of pump, there is usually a cylinder two or three inches in diameter and six or eight inches long. As a rule the cylinder, to which the spout is attached, is placed on the well platform, a short distance above the level of the ground. A tube or pipe extends from the bottom of the cylinder down into the well. Inside the cylinder there is a piston which can be moved up and down by means of the pump handle. [See Fig. 1–11.] The piston fits the cylinder so tightly that air cannot get past it. The piston has a hole in it which may be closed with a valve.

As we push the pump handle down, the piston is pulled upward and its valve is closed. This removes some air from the cylinder of the pump and produces a partial vacuum also in the tube leading into the water. The air pressing down

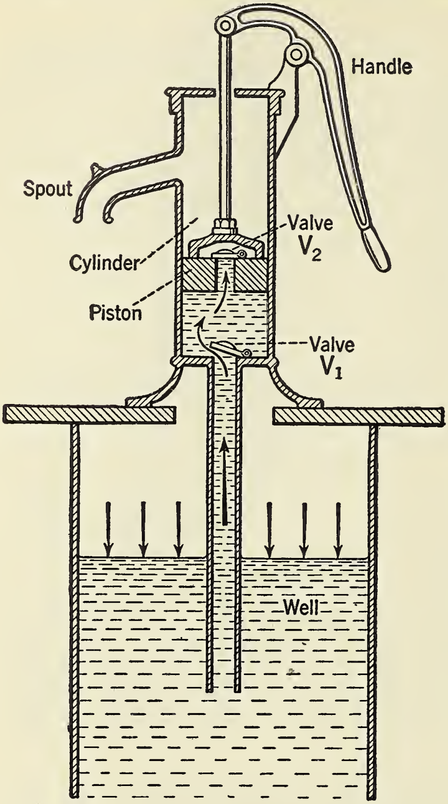


Fig. 1–11. One finds pumps of this kind in many sections of the country. It may be called a suction pump, although it is more commonly called a lift pump. This illustration shows a lift pump as it would appear if it were sawed lengthwise from the top of the pump to the bottom. Of course, both the cylinder and the piston are round.

upon the surface of the water pushes some of the water up through the tube into the bottom of the cylinder. A valve between the tube and the cylinder permits the water to flow upward through it, but it prevents the water from flowing back into the well when the piston is lowered. Just as traffic flows in one direction only through a one-way street, so the valve opens in only one way to permit water to flow in one direction. Where, then, can the water go? The only place it can go is up through a valve in the piston itself. [See Fig. 1–11.] On the next upstroke of the piston, the water is lifted upward and flows out of the spout.

c) *The force pump.* The lift pump described in the pre-

ceding paragraph is much used for shallow wells and cisterns. In deep wells, the force pump is likely to be used. Like the lift pump, the force pump has a cylinder, a piston, and two valves. But the piston of the force pump has no opening in it, and the cylinder is usually placed down in the well from ten to twenty feet above the surface of the water. A pipe leads from the cylinder down into the water.

When the piston is raised, it pushes the air out of the cylinder and leaves a partial vacuum in the pipe beneath the piston. Air pressure upon the surface of the water in the well then pushes some water up into the cylinder. [See Fig. 1–12.] The valve at the top of the pipe prevents the water

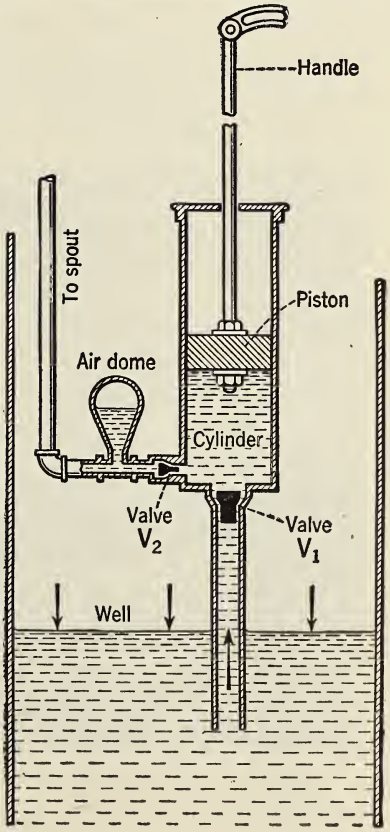


Fig. 1–12. It is possible that you never saw the cylinder of a pump of this kind, because it is often placed down in the well, fairly near the water surface. We call it a force pump because force of some kind must be used to push the water from the cylinder up through the outlet pipe. A windmill may be used to operate such a pump, or it may be operated by a small gasoline engine. Of course, it is possible to use the effort of one's muscles. On the downstroke of the piston, some water is forced into the air dome, thus compressing the air inside. This compressed air expands again during the upstroke and causes a steady flow of water.

from flowing back into the well as the piston is lowered. Since it has no opening, when it moves downward it pushes the water up through the small pipe at the side of the cylinder. Because the water is pushed upward by the piston, this pump is called a *force pump.* A second valve is used at the entrance to the outlet pipe to keep the water from flowing back into the cylinder during the next upstroke of the piston.

12. How are pumps operated? Many pumps are operated by hand, or *man power.* A horse or a cow will drink three or four gallons of water at one time. If a farmer has a half dozen horses and fifteen or twenty cows to water, the pumping of water by hand becomes a real chore. It is especially tiresome if the well is deep and if a force pump must be used to force the water upward to a considerable height. In such cases a farmer may use a windmill like that shown in Figure 1–13, to pump the water up into a large tank, from which it can be drawn for watering his stock or for other use.

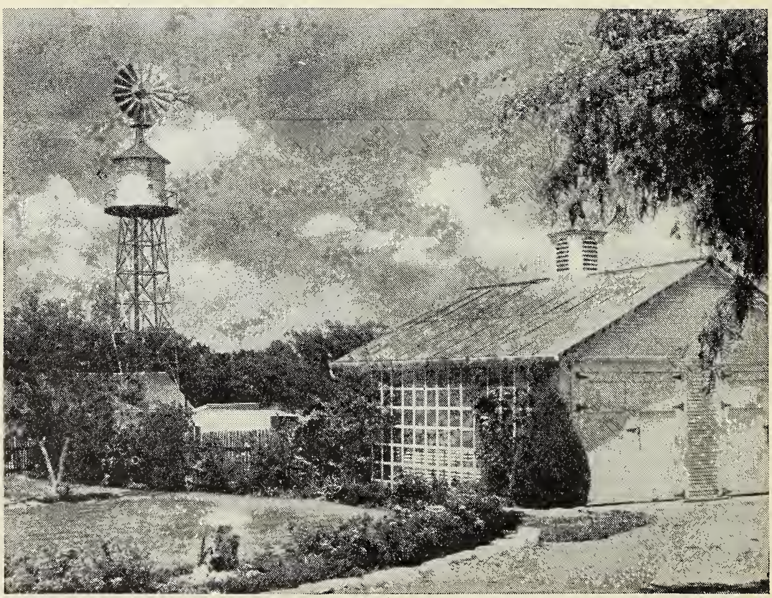


FIG. 1–13. How does this windmill help its owner? (*Courtesy Aermotor Co.*)

Many farmers use a small gasoline engine to pump water and also to generate electricity for use in the home. Some farmers use an electric motor for pumping.

*13. **How does a siphon work?** A siphon (sī′fŏn) cannot be used to carry a liquid from a lower level to a higher level. It can be used, however, to transfer a liquid from one container over an elevation to a container at a lower level. It saves the work of lifting the first container, and it does away with the danger of spilling the liquid. One can siphon water, for example, up over the side of a boat, from the bottom of the boat, to the lake or river beneath, if the boat is pulled up to some distance above the level of the water in the lake or river.

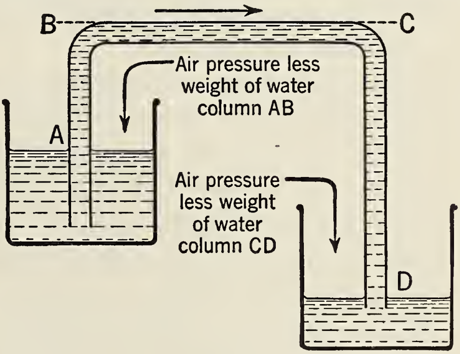


Fig. 1–14. The siphon has many uses. It may be used to draw vinegar from a heavy barrel. It may be used to empty a tank of liquid which is too heavy to lift. It is sometimes used in an effort to avoid spilling liquids which are corrosive.

Before the siphon represented in Figure 1–14 can begin to flow, it must be filled with water. The air pressure at A is supporting, or keeping raised, the water column AB, and the air pressure at D is supporting the water column CD. But the water column CD is longer than the water column AB. Hence it reduces the effect of the air pressure at D until it is less than the effective air pressure at A. Because the effective air pressure at A is greater, the water will flow from A to D.

A siphon may be used to transfer acids from large jars to smaller ones. It is generally made of rubber or of glass.

* Starred problems are intended for rapid pupils only.

14. What is the city water problem? The man who lives at some distance from his neighbors can solve his own water problem at his own expense and by his own efforts. To supply a community with water is an engineering problem. Each inhabitant of a city uses several gallons of water daily for his bath, for laundry work, for washing dishes, for washing cars, for watering lawns and gardens, and for various other purposes. Some cities are supplied with water from rivers and purify the water to make it fit to drink. Others, like Chicago, Buffalo, or Cleveland, secure their water supply from bodies of fresh water such as the Great Lakes. Many cities, like Boston, Newark, Los Angeles, or New York buy many acres of land in the neighboring highlands. Then they build dams across the streams to form reservoirs. *Aqueducts* are then built to carry the water from the reservoirs to the cities themselves.

New York City, for example, owns land in the Catskill Mountains more than one hundred miles from the city. The Ashokan (*ȧ*·shō′k*ă*n) Dam built by the city makes a reservoir, or lake, about ten miles long and a mile in width. Water from this huge reservoir is conducted through an aqueduct to the Hudson River and under the river through a tunnel nearly 15 feet in diameter. This tunnel was dug through solid rock about 1100 feet below the river. Then the water is carried down the Hudson to New York City. A second tunnel, 11 feet in diameter, carries the water under the East River to Brooklyn. The cost of this great project was $200,000,000. The 130,000,000,000 gallons of water which the reservoir holds can supply each inhabitant of New York City with at least 100 gallons of water daily.

Los Angeles receives water from the melting snows of the Sierra Nevada Mountains through an aqueduct 16 feet in diameter and 392 miles in length. This famous aqueduct carries about 1,000,000,000 gallons of water daily to Los Angeles and other cities of southern California. At some places it crosses highlands over 1600 feet in height. It con-

sists of tunnels, concrete and steel pipes, and canals lined with concrete. It dwarfs all other aqueducts, ancient and modern, with its capacity of 400 barrels of water a second.

15. How does the water get from a lake to the top of a tall city building? Of course water does not flow uphill. In some cases the reservoir is situated at a lower level than the city buildings which it must supply. In such cases a water-pumping station must be installed. [See Fig. 1–15.]

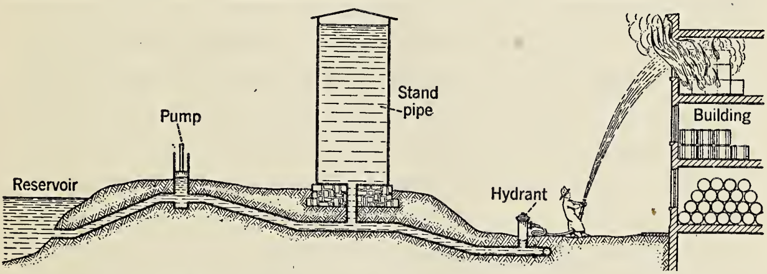


FIG. 1–15. The pump is used to pump water from the reservoir and to force it up into the standpipe, which is tall enough to furnish pressure for fighting fires effectively.

From the reservoir, water may be pumped by means of a force pump up into a large standpipe which holds considerable water. From the standpipe, or directly from the pump, water flows to the street *mains*, or pipes. A hose attached to the hydrants connected with the water mains is used for fighting fires. From the street mains, pipes lead to the various dwellings and office buildings of the city.

16. How is water purified? Usually, as you have read, mineral matter dissolved in drinking water is not injurious. It is costly to remove such mineral matter, and generally no attempt is made to do so. It is necessary, however, to remove the mineral matter carried in suspension in the water, because no one cares to drink water which looks turbid, or muddy. Organic matter which may be in the water may be harmless in itself. However, it must be destroyed in some manner so that it will not provide food for disease-producing

bacteria. It is not necessary to remove such bacteria from the water, but some method must be used to kill them. A part of the problem of securing wholesome water consists in keeping the areas around the reservoirs free from material that might contaminate the water. If a city, for example, uses water from a river, care must be taken to make certain that the water is not polluted by sewage from any source, from the city itself or from another city some five or ten miles upstream.

17. How is matter in suspension removed from water? If water is permitted to trickle through a sandy soil, the particles of solid matter which it may be carrying are strained, or filtered, out. Men use this *natural purification of water by sand filtration* in order to purify water which carries material in suspension.

First the running water is permitted to flow into a large basin and stand for a few hours. Much of the material settles at the bottom of such a settling tank or basin. Then the water is gradually drawn off from the settling basin and permitted to pass down through tanks filled with gravel and sand. The sand strains out the solid particles which were too small to settle quickly. Sometimes charcoal is used in the filtration tanks because it can remove coloring matter and disagreeable odors from the water. [See Fig. 1–16.]

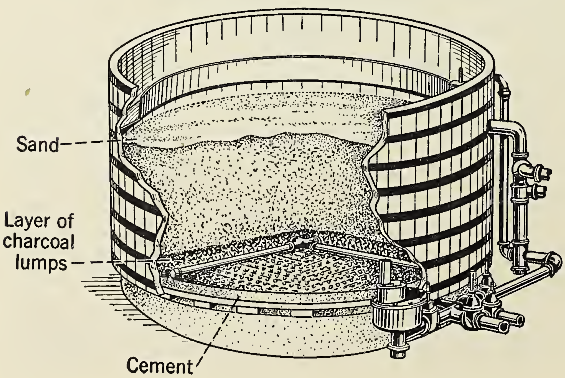


Fig. 1–16. In this filter, the sand strains particles out of the water, and the charcoal removes coloring matter and odors.

In Washington, D. C., and Toronto, Canada, large beds of sand several acres in extent are used to filter the water before it flows into the water mains of the city. The water is freed from matter in suspension as it percolates through the beds of sand.

18. How are bacteria destroyed? It is true that many of the bacteria are removed when water is filtered. Some of them, however, may pass through the filter, and they must be destroyed. Several methods are used to kill bacteria:

a) *Air and sunlight.* Fresh air and sunlight, working together, make the best disinfectants known. Running water exposed to air and sunlight tends to purify itself. Even sewage can be purified by *aeration*. Figure 1–17 shows how the water in the Ashokan Reservoir is aerated and exposed to sunlight before it starts on its long trip to New York City.

b) *Boiling.* This method of purifying water is used only for small amounts of water. If you are not sure whether the water you plan to drink is wholesome, you had better boil

FIG. 1–17. The Ashokan Reservoir has a beautiful aeration plant. Oxygen and the energy of sunlight both work to destroy bacteria. (*Courtesy Board of Water Supply of New York City*)

the water and then cool it before you drink it. Boiled water has a flat taste, but its insipid taste may be remedied by aerating the water after it has been boiled. Such aeration may be done by pouring the water back and forth from one glass to another several times so that the water may again dissolve air to take the place of that driven out of the water during the boiling.

During the floods along the Ohio River in the spring of 1937, many towns and cities could not get water from usual sources. During this emergency, persons were advised to boil their drinking water to kill any bacteria that might have been present. Some persons added a few drops of *tincture* of iodine (which is iodine dissolved in alcohol) to a glass of water before drinking it. Iodine is useful in destroying bacteria, but its use must not be continued after the emergency has passed.

c) *Chemicals.* Probably no chemical is more widely used to destroy bacteria in water than the greenish-yellow gas

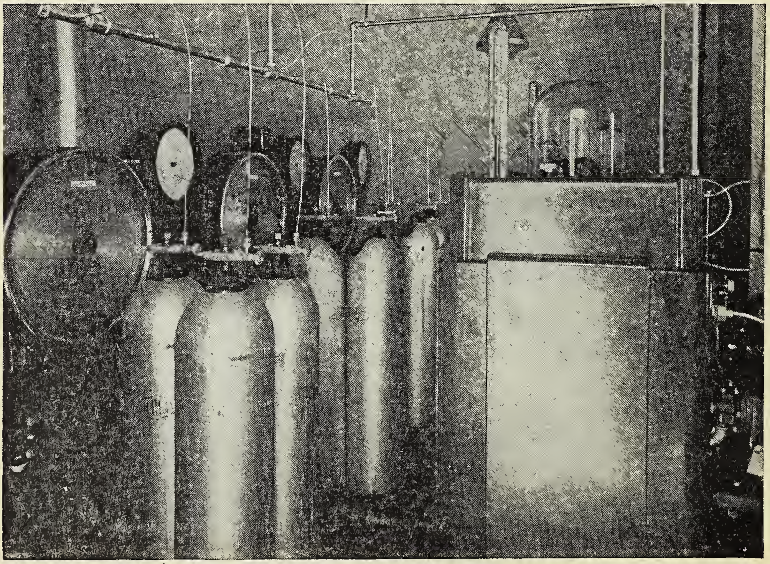


FIG. 1–18. The chlorinator at the right uses the chlorine in the cylinders to kill bacteria. (*Courtesy Wallace & Tiernan Co., Inc.*)

known as *chlorine* (klō′rēn). Small quantities are added to drinking water, and somewhat larger quantities are used to disinfect the water in swimming pools. It is a very effective *germicide* (jûr′mĭ·sīd), a substance which kills bacteria or germs. Sometimes the chlorine gives the water a slightly unpleasant taste, but safety is more important than complete enjoyment. [See Fig. 1–18.]

Ozone is a gas which is merely a very active form of oxygen. When it is added to water, it destroys the bacteria that are present. As it destroys the bacteria, it changes back to oxygen. For that reason it does not leave in the water any undesirable odor or taste. Ozone is not much used in the United States to purify water, but it has been used in some European cities. In some localities water which has been treated with ozone is bottled and sold as "electrified water."

Copper sulfate is an important chemical often called *bluestone* or *blue vitriol.* It is a very active germicide. One part copper sulfate in ten million parts of water will, it is claimed, destroy the bacteria that cause typhoid fever. Copper sulfate is useful, too, in destroying the fresh-water plants known as *algae,* which are often found growing in city reservoirs. You are probably familiar with algae as the greenish slime found on stagnant water, and often called by the name *pond scum.* This is one kind of algae. Another kind secretes an oil which gives to the water a disagreeable odor and taste. In some cases the odor is not unlike that of a pigpen. Water containing such algae has a disagreeable taste, but it is not harmful.

d) *Distillation.* By the process of *distillation* we can get water which is almost absolutely pure. We simply evaporate the water by boiling it, and then condense its vapor. Let us set up an apparatus like that shown in Figure 1–19. Into the flask we pour some water which contains mineral matter in solution and also particles which are held in suspension. Then we heat the water to boiling and keep it boiling. When the water boils, it changes into the gas known as

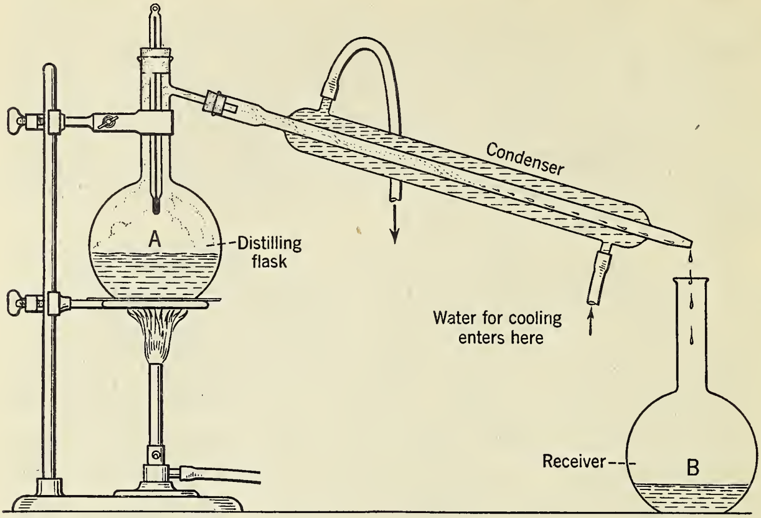


FIG. 1–19. The liquid is changed into vapor in the distilling flask. As the vapor passes through the condenser, it is cooled and changed back again to the liquid form, but purer than it was before.

water vapor. As the vapor goes through the condenser, which is jacketed, or covered, so that cold water can flow around the inside tube, the vapor is condensed into drops of pure, liquid water. The distilled water is collected in the flask B. The mineral matter, both that carried in suspension and that held in solution, remains behind in the flask. Distilled water is used in chemical laboratories for making up solutions. The water that is added periodically to storage batteries should be distilled to free it from all mineral matter. Bacteria are destroyed by distillation.

The water cycle, which you have studied earlier, is an example of natural distillation. Water evaporates and forms an invisible vapor. When such vapor condenses, it forms clouds. When the vapor is further cooled, it may condense into drops which fall as rain. Hence "rain water" is really distilled water, and the poet is not incorrect when he uses the line: "And gently distills as the dew and the rain."

19. How do we use water to get rid of wastes? After we have used water for our bath, the waste water is permitted to flow out through a pipe which connects the bathtub to the sewer. When the dishes are washed, the water is permitted to flow down through the outlet pipe to the sewer. Possibly you may have wondered why there is a U-shaped bend in the outlet pipe just beneath the sink. [See Fig. 1–20.] That goose-neck turn serves two purposes. First, it

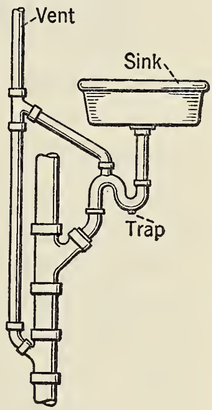


Fig. 1–20. The U-shaped trap in your kitchen sink or beneath your laundry tubs serves at least two purposes. It may catch solid refuse which might clog the pipes. In such a case, it can easily be opened and cleaned.

Water stands in the rounded portion at all times and serves as a seal to prevent sewer gas from getting into your house. Do you think the trap is a siphon?

collects those solid particles that might eventually clog the pipe. A nut screwed into the bottom may be easily removed to permit the bent portion of the pipe to be cleaned. Second, water always stands in the bent tube, because there is a vent pipe at the upper turn which prevents the pipe from acting as a siphon. The water which stands in the U-shaped part of the pipe serves as a seal and prevents sewer gas from entering the kitchen.

The tank for flushing the toilet holds about three gallons of water. When the tank is flushed, a *lever* (lē′vẽr) lifts a rubber ball and permits the water to flow out through the toilet rapidly enough to carry away waste material. Then the ball drops down to check the flow of water. The tank fills with water, and as it does so, a hollow ball attached to

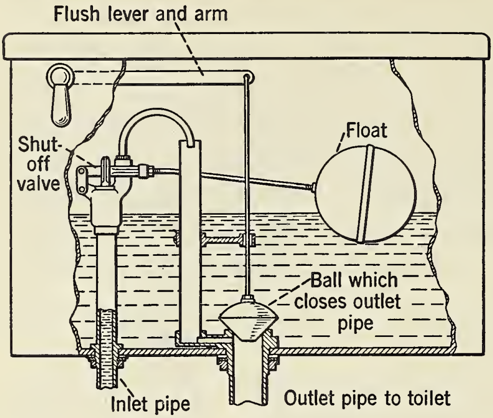
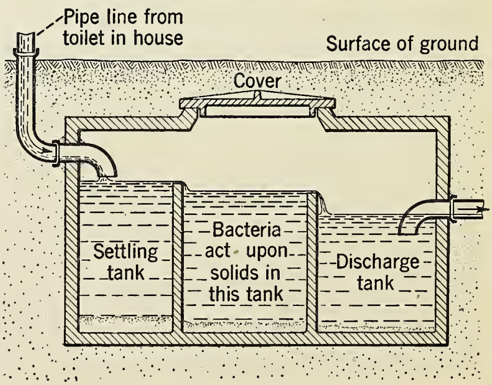


FIG. 1–21. What makes the ball in a flush tank float and shut off the water? What happens if the ball springs a leak? What is the purpose of the rubber ball in the bottom of the tank? Why must it be renewed every few years?

one end of a lever floats higher and higher. Finally it reaches a position in which the lever closes a valve and prevents more water from flowing into the tank. [See Fig. 1–21.]

Many farmers now have running water for their houses. A storage tank is placed at some elevation aboveground. It may be out-of-doors, in the hayloft, or upstairs in the house itself. In the absence of a sewer to which the waste pipes can be connected, a *septic* tank may be built and buried underground. Figure 1–22 will help you to understand the way a septic tank works. The tank is built of metal or concrete and is divided into two or three compartments sepa-

FIG. 1–22. It is an interesting fact that bacteria aid man by causing decay. Sewage is destroyed by the action of such bacteria. Can you name any other bacteria that are friends to man?



rated by concrete walls. The walls vary in height. The sewage from the toilets runs directly into the first tank. The solid particles settle at the bottom of the tank, and the lighter parts flow over into the second tank. From this tank, too, the lighter parts of the sewage flow into the next tank. Bacteria act upon the sewage in the three compartments until it is well *decomposed.* Then in decomposed form, the sewage flows from the third compartment of the tank as a clear, odorless fluid. This may pass into sand filters buried in the soil. Sometimes it is collected and used as a fertilizer. Septic tanks are also used for sewage disposal in some cities.

Sewage is sometimes permitted to flow away into a cesspool, which is a hole in the soil some ten or twelve feet deep. The sides of the cesspool are walled up with brick or stone, and the top is covered. The solids are broken up by the bacteria which cause decay and the liquid portion drains away into the soil. Cesspools work satisfactorily if the soil is sandy, but they must never be located near a well, and the water from them must never drain toward a well. They are not sanitary in clay soils where the liquid from them seeps away slowly. The septic tank is a much safer method of disposing of sewage wastes.

20. What does the term "hard water" mean? Rain water is "soft" water. It has little or no mineral matter dissolved in it. As such water flows over rocks or trickles through the soil, it dissolves small quantities of mineral matter. In many cases, the mineral matter thus dissolved consists of compounds of calcium, magnesium, or iron. If you use soap with water containing such compounds in solution, you find that the soap unites with the minerals to form *insoluble* (ĭn·sŏl′ū·b'l) compounds, or compounds which cannot be dissolved. This insoluble compound forms the ring seen on the wash basin or on the bathtub when soap is used with such water. We call the water "hard" if it contains mineral matter that will "curdle" soap. Water which contains from 40 to 50 parts of such mineral matter per million parts

of water is noticeably "hard." If there are from 150 to 200 parts of mineral matter per million parts of water, the water is said to be "very hard."

21. Why is hard water undesirable? In the first place, hard water wastes soap. It is impossible to form suds until enough soap has been used to combine with all the mineral matter present in the water. It is rather difficult to remove the ring formed on the wash basin or on the bathtub. The insoluble compound formed by the curdling of the soap accumulates in dishwater. It gets into the fibers of the clothing that is being washed in the laundry. It is difficult to rinse the clothing so that it will be free from the solid particles formed by the action of the soap on the hard water. If the hardness of the water is due to compounds of calcium, the solid particles formed with the soap are known as "lime soap." They do not cleanse; they only get in the way and leave ugly rings on the sides of tubs, sinks, and lavatory basins.

In your hot-water tank, hard water will deposit mineral matter in the form of scale or crust. The same thing happens in your steam boiler. Then it takes longer to heat the water because such scale does not conduct heat very well.

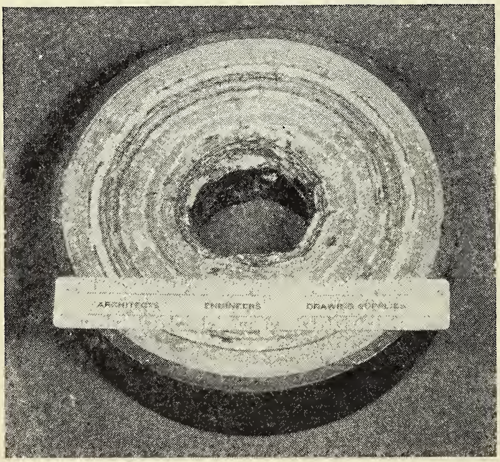


FIG. 1–23. As water evaporates in the pipe, it leaves layers of sediment and mineral matter. Water pipes and steam pipes may become entirely clogged with scale such as is shown here. The ruler is a six-inch ruler. (*Courtesy The Permutit Co.*)

Thus hard water is responsible for the wasting of gas or other fuel used to heat the water in dwelling houses. Sometimes the pipes of steam boilers become entirely clogged by the continual formation of one layer of scale upon another. [See Fig. 1–23.] Automobile radiators, too, may become clogged by the mineral matter from hard water.

Newark, New Jersey, has an abundant supply of soft water. A neighboring suburb of Newark has rather hard water. In which place would you prefer to start a laundry? Many industries are located in the city of Newark because an abundant supply of soft water is available there. Many chemical concerns are located in or near Newark. It is the center of the leather industry, in which soft water is desirable and important.

22. Is hard water injurious to health? No one can answer this question satisfactorily. Our bodies need compounds of calcium if the bones and teeth are to develop properly. Some doctors believe that we cannot take the calcium we need from the mineral matter present in hard water, but that we must get our supply from milk, the skins of fruits, whole wheat, and other foods. Other doctors are just as certain that we can use the mineral matter present in hard waters.

One thing seems to have been fairly well proved. Persons who have lived for years in a locality where the drinking water is hard do not seem to suffer any ill effects from drinking such water. It is also true that persons who have lived for years in a locality where the water is soft get along very well without depending upon mineral matter found in hard water. Sometimes persons long accustomed to the use of hard water suffer some bad effects when they move into a place where the water is very soft. The same thing is true when persons accustomed to drinking soft water move to a locality where the water is hard. Apparently we can accustom ourselves to live very well by the use of either soft water or hard water.

***23. How can hard water be softened?** Some kinds of hard water can be softened by boiling the water. Such a method is expensive, and it does not work with all kinds of mineral matter. Several different chemicals are used to soften hard water. One of the most common ones is *washing soda.* It is also one of the cheapest. It not only softens water, but it aids in removing grease from dishes and clothing. Many scouring powders consist largely of washing soda, powdered sand, and powdered soap.

Borax is another chemical that is useful for softening hard water, but it is too expensive to be used on a large scale. Some persons add a little borax to the water before they take a shampoo.

Tri-sodium-phosphate is another of the many different chemicals which find use in softening hard water. It is useful for preventing the ring sometimes formed on the sides of a bathtub when soap has been used with hard water.

Several different manufactured chemicals can remove the hardness of water by filtration. The chemicals are packed in a tank and the hard water flows into the top of the tank, percolates down through the chemicals, and then runs out of the bottom of the tank, almost completely softened.

Questions

1. Why do you need a supply of wholesome water?
2. What is the difference between *pure* water and *wholesome* water?
3. In what two ways can one get rid of solid matter carried by water in suspension?
4. Why is organic matter in water so objectionable?
5. How is it possible to free water from mineral matter which is held in solution in the water?
6. What are some of the methods of destroying bacteria in water?

7. If you have a deep well, would you use a force pump or a lift pump?

8. Which would you use to pump water up into a tank in the haymow, a lift pump or a force pump?

9. Make a list of at least a half dozen diseases that are caused by bacteria.

10. Suppose you are moving into the country. What precautions would you take in locating a place to dig a well?

11. For what purposes are siphons used?

12. Can you siphon water from a vessel on the first floor to one on the second floor? Explain your answer.

13. Where does your city get its water? How is the water made wholesome? Why is purification by boiling used only for small quantities of water?

14. In what industries is the use of hard water objectionable? Why?

15. Why is the septic tank more sanitary than a cesspool?

16. Why does one so often see "No trespassing" signs upon the land areas used as a water supply for cities?

17. Can you explain why a person who lives in a flooded area must be particularly careful to purify the water before he drinks it? Is it also true that water from reservoirs that are at low levels from long drought is likely to be dangerous to drink?

Some things for you to do

1. Write a two-hundred-word essay on the subject "Bacteria as friends of man."

2. Fill a test tube half full of water that is rather hard. Add a drop of a dilute solution of soap. It is better to have the soap dissolved in alcohol. Shake the tube. Do suds form? Keep adding the soap, a drop at a time, shaking the tube after each drop is added, until the suds that form remain for some time. Repeat the experiment, using a test tube half full of distilled water. What difference do you notice in the amount of soap necessary to form suds?

3. Make a siphon like that shown in Figure 1–24. Put a pinch

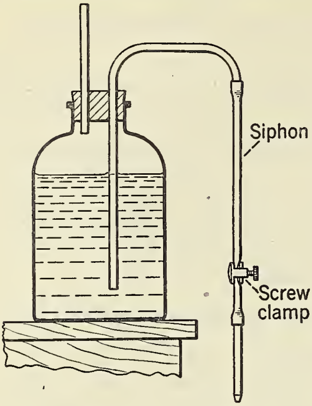


FIG. 1–24. What happens to the air in the bottle when you open the screw clamp and blow through the short tube? What happens to the air in the bottle? Can you fill the siphon with liquid by blowing through the short tube? Will the siphon start to flow as a result?

clamp on the rubber tube. Loosen the pinch clamp and blow into the straight glass tube. What happens?

4. Fill a tumbler a little more than half full of lukewarm water. Add a few pieces of ice and stir the ice and water with a spoon. Keep adding ice and stirring until you notice some change on the outside of the tumbler. What happens? Explain why.

5. Have you ever seen a well sweep? If not, look it up in a reference book. Make a sketch of one showing how it works.

Weather and Climate Affect Our Daily Lives

UNLIKE our water supply, our weather supply seems to be beyond our control. Wherever we live, we have weather and a climate. Probably wherever you go, you talk about the weather and hear others talking about it. Does it seem a mysterious thing to you? Do winds and rain and changes in temperature follow each other in a haphazard way?

In Unit 2 you will find that our weather follows certain patterns, from day to day. It is possible to study these patterns and often to predict the weather, even though we cannot change it. The larger patterns of weather over long periods of time can be studied too. These larger patterns explain climate. Both weather and climate affect our lives and make many of our decisions for us. They determine, for example, what crops our farmers may raise and at what hour our fishermen shall go out to sea. Weather and climate have much to do with our environment.

Think about these!

1. What are some ways in which the weather comes into your life and affects the things that you do?

2. Is the weather forecaster a prophet or a scientific worker?

3. What is wind? Why do winds blow from different directions?

Words for this chapter

Isobar (ī′sȯ·bär). A line drawn through places which have the same atmospheric pressure.

Barometer (bȧ·rŏm′ė·tẽr). An instrument used to measure air pressure.

Isotherm (ī′sȯ·thûrm). A line drawn through places which have the same temperature.

Precipitation (prė·sĭp′ĭ·tā′shŭn). The condensing of water vapor into drops which fall to the earth as rain, sleet, or snow.

North Temperate Zone. That portion of the globe north of the equator that lies between the Torrid Zone and the polar circle.

Clockwise. Turning in the same direction in which the hands of a clock move.

Cyclone (sī′klōn). A large storm in which the barometer readings are relatively low.

Anticyclone. A storm in which the barometer readings are high.

CHAPTER 2 ——— UNIT 2

What Is Weather?

24. What is weather? One way to answer the question "What is weather?" is to look at one of the weather maps published in normal times by the United States Government, or at a similar map. [See Fig. 2–1.]

a) First you will find a number of heavy, unbroken lines drawn upon the map and marked in inches. Such lines are called *isobars,* and are drawn through the names of the places in the country which have the same air pressure, as measured by the *barometer* at a particular time. Some of these isobars are closed curves surrounding areas which have low barometer readings, and others surround areas which have high barometer readings.

b) You will probably find on this weather map at least two dotted lines extending in a general east and west direction across the United States. Such lines are called *isotherms.* They are drawn through those places which have the same temperature. For example, the isotherm marked 30° F. is drawn through all those places where the tempera-

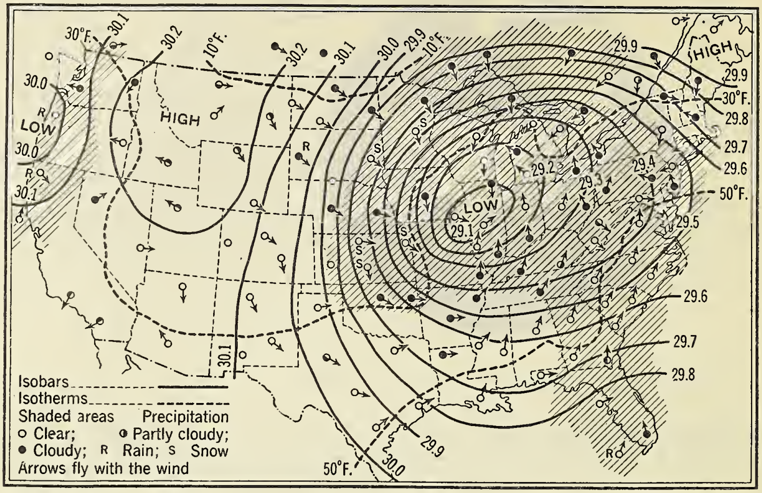


FIG. 2–1. The " low " which is central over Chicago is bringing rain to much of the eastern half of the United States. What kind of weather will the " high " over Montana furnish the same area a few days later?

ture was exactly 30° F. when the reports were sent in to a central office from the various weather-observation stations.

c) You will also find on the map some arrows that show the direction in which the wind is blowing. The arrows fly with the wind.

d) At one end of the arrows and elsewhere you will see a small circle. The plain circle ○ shows that the sky is clear. The partly shaded circle ◑ shows that the sky is partly cloudy. The letter R shows rain at that station; the letter S shows snow. The letter F would indicate fog.

e) In addition to the conditions shown on the weather map itself, weather observers at government stations also send information concerning the following: the *velocity*, or speed, of the wind, the amount of rainfall or other *precipitation* within the preceding twenty-four hours, the lowest temperature within the preceding twenty-four hours, and the highest temperature within the preceding twenty-four hours.

From our study, then, of a government weather map, we may summarize what we mean by weather as follows: (*a*) the temperature and its daily variations; (*b*) the kind of precipitation and the amount; (*c*) the direction of the wind and its velocity; (*d*) the condition of the sky, whether clear, partly cloudy, or cloudy.

Barometer readings are not exactly a part of weather conditions, but we shall learn that a knowledge of barometer readings is absolutely necessary for forecasting weather.

25. What is a barometer? As you may recall, the Italian scientist Torricelli used a glass tube about three feet long, and closed at one end. He filled that tube with mercury, put his finger over the open end, and then inverted the tube and placed the open end in a bowl of mercury. [See Fig. 2–2.] When he removed his finger, only a part of the mer-

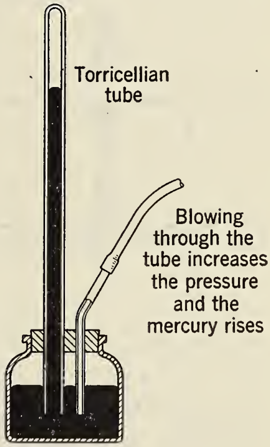


FIG. 2–2. Blaise Pascal, a Frenchman, was not completely convinced that the mercury in a Torricellian tube is supported by air pressure. He asked his brother-in-law to make such an apparatus and carry it to the top of a mountain. Part of the mercury flowed out of the tube as it was being carried up the mountain. Why do you suppose this happened?

cury flowed out. The portion which remained in the tube was held there by the pressure of the air on the surface of the mercury in the bowl. When the air pressure increases, the mercury in the tube rises. We say that the barometer rises. When the air pressure on the surface of the mercury decreases, the mercury in the tube drops. We say that the barometer falls.

We may show how a change in the pressure upon the surface of the mercury in the bowl affects the barometer reading by using the apparatus illustrated in Figure 2–2. When we blow through the rubber tubing, the mercury rises. If we suck upon the end of the rubber tubing, the mercury falls.

All we need to do to change a Torricellian tube into a barometer is to attach to it a scale, so that it will be possible to read the height of the mercury column. When we read this *mercurial* barometer, we merely measure the distance from the surface of the mercury in the bowl to the top of the mercury column in the tube.

26. What is an aneroid barometer? The word *aneroid* (ăn′ẽr·oid) means *without liquid.* The aneroid barometer has no liquid in it. One of its essential parts is a small disc-shaped metal box, as shown in Figure 2–3. Part of the air

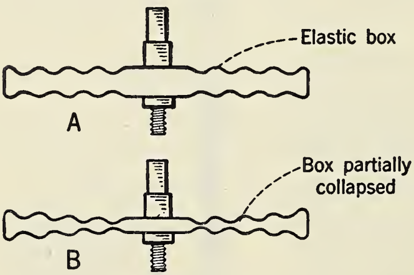
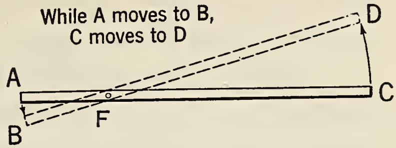


FIG. 2–3. The elastic box, A, contains air at reduced pressure, or at pressure less than that of the atmosphere. If the outside air pressure increases, the box partially collapses, as shown in B.

is removed from the box, and it is then sealed to keep out all air. The bottom part of the box is attached firmly to the base of the instrument. The top part is fluted, or ridged, to make it springy. It is made of thin metal which is so elastic that it is easily pushed downward when the air pressure increases, and it rises again as the air pressure decreases. The movement is so slight that it can scarcely be seen.

A slight movement, however, can be multiplied into one that is much larger. A lever is used to do this. Let us look at Figure 2–4. The arm AF of the lever AC is one inch long. The arm CF of the same lever is ten inches long. If we pull

FIG. 2–4. Hold a broom handle with your left hand one foot from the end. Use your right hand to push the end of the handle down one foot. How much does the broom move?



downward at A and move it only *one-tenth* of an inch, then the point C will be moved upward *one inch*. Thus such a lever multiplies a small movement, and makes it possible to detect extremely slight movements. A bent lever of the type shown in Figure 2–5 may be used in a similar way.

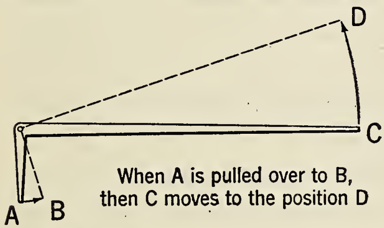
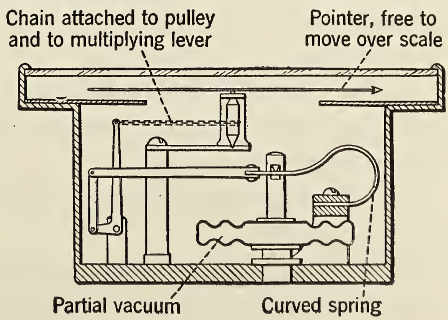


FIG. 2–5. Levers are frequently used to multiply tiny movements, even those which are too small to be measured directly.

If we attach the short end of a multiplying lever to the elastic top of the metal box, then we have a sensitive barometer, because we can easily measure the slightest movements of the top as the air pressure upon it changes. Two or three multiplying levers may be used. The longer end of the lever is attached to a string which is so fastened to the axis of a pointer that the pointer will move back and

FIG. 2–6. As the top of the elastic metal box of an aneroid barometer moves up and down in response to changes in air pressure, the multiplying levers move even more and shorten or lengthen the chain which is fastened to the axis of the pointer.



forth across a scale. The corresponding changes in air pressure can be read from the scale. [See Fig. 2–6.]

27. Which kind of barometer is better? The aneroid barometer, which is more convenient than the mercurial barometer, varies in size from an instrument about the size of a watch to one that is about as large as a good-sized alarm clock. Since the mercurial barometer must be about three feet long, it is not easily carried from place to place.

The aneroid barometer may be placed without injury in any position. It will read correctly right side up, upside down, or in a sidewise position. Can you imagine what would happen to a mercurial barometer if an aviator took it up in an airplane and "looped-the-loop"? Do you think it would read correctly on a rolling ship? If we are to get a correct reading with a mercurial barometer, we must always keep it in a vertical position.

Possibly you are wondering why we use mercurial barometers at all. We must have a mercurial barometer with which to compare an aneroid barometer before it can be set and graduated correctly. If you buy an aneroid barometer, it will need to be adjusted for the altitude of the place at which you live.

28. For what purposes are barometers used? If we are to forecast weather with any degree of accuracy, a barometer must be used. Some of the weather indications are as follows:

a) A relatively high barometer reading indicates fair weather, with reasonably clear skies, and temperatures below normal.

b) A relatively low barometer reading indicates stormy weather, with skies overcast, possibly rain or snow, and temperatures above normal.

c) A rapidly falling barometer indicates the approach of stormy weather.

d) A rising barometer indicates the clearing up of a storm and the approach of better weather.

In a later section you will learn why an observer at any one place cannot tell much about coming weather conditions from a single reading of the barometer.

The barometer is also used to measure altitudes. The mercury drops about one inch for every 900 feet one ascends. A barometer much used by aviators is so graduated that it reads "altitude in feet" instead of "air pressure in inches." Such a barometer is called an *altimeter* (ăl·tĭm′ē·tẽr).

29. Why do barometer readings vary? We expect barometer readings to vary in different parts of the United States, because altitudes vary. We know that the air pressure is less at Denver than it is at St. Louis. Can you tell why this is true? But how can we explain the fact that the readings of the barometer will vary from day to day at any given place? There are two important reasons:

a) When air is *heated,* it *expands.* The air then becomes less dense as it expands. This fact explains why we expect to have high temperatures causing relatively low barometer readings. Unequal heating of the air in different localities, and unequal heating of the air in the same locality at different times, will cause barometer readings to vary from day to day.

b) Many persons think that "moist air" is denser than "dry air." They are accustomed to hear the air described as *heavy* on a humid day. Actually, they are wrong. *One cubic foot of moist air is less dense than one cubic foot of dry air.* Water vapor is less dense than dry air, and when we mix water vapor with dry air, the mixture is also less dense than is the dry air. The amount of moisture present in the air varies in different places and at the same place at different times. Hence, barometer readings will vary with the amount of moisture present in the air. Increasing the amount of moisture in the air will cause the barometer reading to become lower.

30. What causes winds? A wind is really a stream of air in motion, much like a stream of water in motion. Why does

water flow downhill? Can you give an explanation? Suppose that for a moment the water at one end of a tank stands higher than it does at the other end of the tank. By experiment, man has learned that the pressure of water increases as its depth increases. So, since water will flow downhill, or from high pressure to low, the water in the deep end of the tank will flow toward the shallow end of the tank, where the pressure is less. It will continue to flow until the water is level, or until the pressures are equal at all places.

Suppose one looks at a barometer at Toledo, Ohio, and finds that it reads 30.5 inches. He has someone read a barometer at Cleveland, Ohio, and he learns that it reads only 30 inches. The air pressure at Toledo is one-half inch of mercury (which is equal to about 7 inches of water), greater than it is at Cleveland. Just as water flows downhill, so air flows "downhill," or from high-pressure areas to low-pressure areas. Therefore the wind will blow from Toledo toward Cleveland.

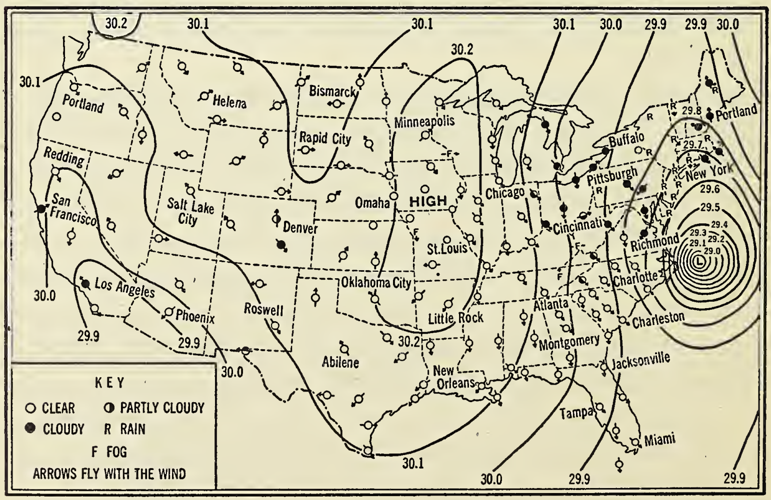


FIG. 2–7. Notice the closely crowded isobars around the center of this hurricane, which has an extremely high velocity.

The steeper a hill, the faster water will flow down that hill. If the pressure at Toledo is increased to 31 inches of mercury, and if the pressure remains only 30 inches of mercury at Cleveland, then the air will flow downhill faster than it did before. The velocity of the wind will be greater, and the wind will blow with more force.

The greater the difference in pressure between two places, the harder the wind will blow from one place to another. The nearer together the two places are, the higher will be the velocity of the wind. *Closely crowded isobars* on a weather map indicate strong winds or gales. See the weather map of Figure 2–7, which shows a tropical hurricane.

31. How do the winds blow in the tropics? If we were to start a fire in the center of a large room, we would soon find that air currents are being set up as shown in Figure 2–8. The air directly over the fire is heated. It expands

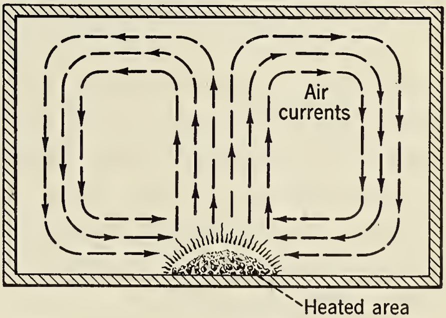


FIG. 2–8. The air above a heated area expands. Thus it becomes less dense, and it is pushed upward by the colder, denser air which flows in toward the center. Such air currents will then distribute heat to all parts of the room.

and becomes less dense than the air in the other parts of the room. The colder, denser air creeps toward the center of the room and pushes the less dense air above the fire upward toward the ceiling. Note the direction of the arrows. At the ceiling, the warm air moves outward toward the sides of the room, cools off, and then moves downward.

The following experiment will show how currents are set up in *liquids* that are unequally heated. We shall first fit

a small Erlenmeyer flask [see Fig. 2–19], 125 cubic centimeters in capacity, with a two-hole rubber stopper in which are two glass tubes. We fill the flask with a one-per-cent solution of *potassium permanganate,* and heat the flask until it is too hot to touch comfortably. You will notice that the liquid expands as it is being heated and that some of it overflows. After having wiped off the excess liquid, we then lower the flask into a large aquarium jar filled with cold water.

What happens now? We can see the cold water flowing in through one of the glass tubes and pushing the colored solution up through the water to the top part of the aquarium. Currents of this kind may be set up in *liquids or in gases* when the masses are *unequally* heated. In liquids we can watch the circulation.

About the twentieth of March and the twentieth of September the sun's rays are shining directly upon the equator. The air over the equator is highly heated, and it expands. It is pushed upward by the cooler, denser air flowing toward the equator from those areas near the *Tropic of Cancer,* the great circle parallel to the equator on the north, and the regions near the *Tropic of Capricorn,* the great circle parallel to the equator on the south. For some reason which no one has been able to explain, there are rather high barometric pressures at all times over areas near the Tropics of Cancer and Capricorn. The circulation then takes place as follows. [See Fig. 2–9.]

a) There is an upward movement of air at the equator. That is known as the *equatorial calm belt.* In the calm belts, currents of air are rising or falling. We do not call air movements "winds" unless the air moves along the earth's surface.

b) There are downward movements of air in those areas near the Tropic of Cancer and the Tropic of Capricorn. These downward movements of air form what are known as the *calms of Cancer and Capricorn.*

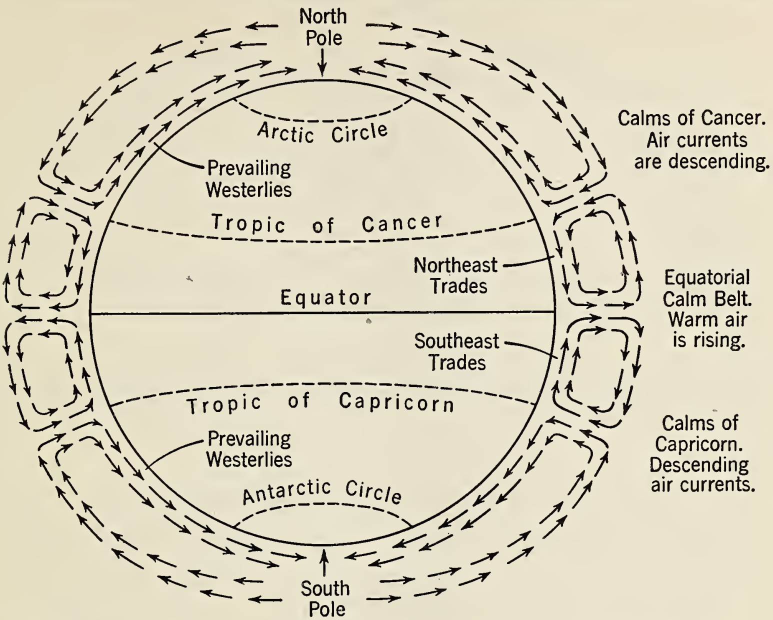


FIG. 2–9. This diagram shows how convection currents cause the equatorial calm belts, the trade winds, and the calms of Cancer and Capricorn.

c) From the tropics the winds blow toward the equator along the surface of the earth. These winds are the *trade winds.*

d) Some distance above the surface of the earth the air currents drift from the equator toward the tropics. [See Fig. 2–9.]

When we have our summer in the northern hemisphere, the direct rays of the sun are north of the equator, possibly as far north as the Tropic of Cancer. Then the equatorial calm belt is pushed north of the equator; the calms of Cancer are pushed northward into the southern part of the *North Temperate Zone;* the trade winds lie between the two. Of course there is a shift northward of the calms of Capricorn and of the trade winds which are between them and the equator. [See Fig. 2–10.]

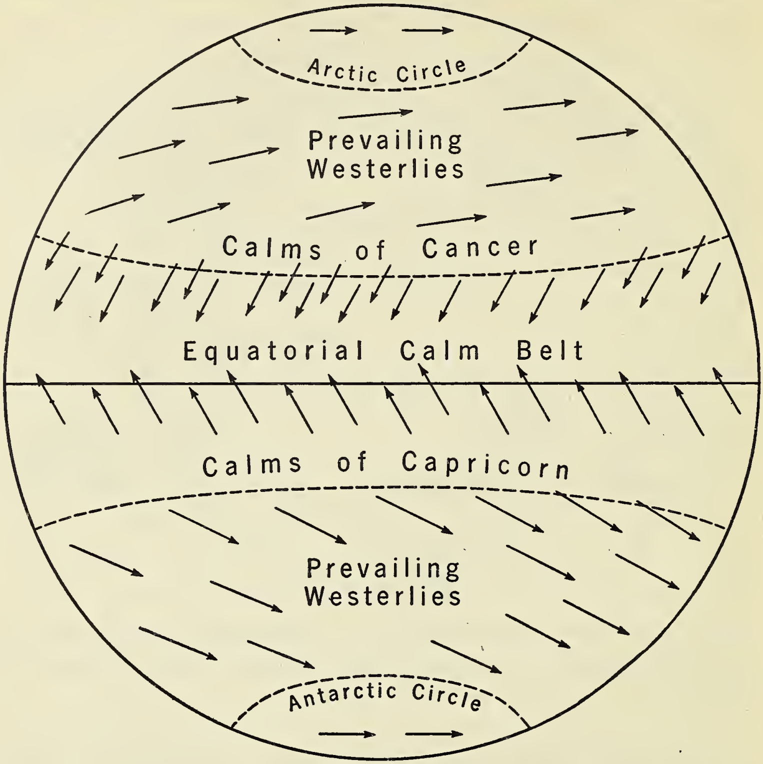


FIG. 2–10. When the northern hemisphere has summer, the equatorial calm belt and the trade winds shift northward.

When we have our winter, the direct rays of the sun are south of the equator, and the trade winds and calm belts move toward the south. [See Fig. 2–11.]

32. What determines the direction of the trade winds? If the earth did not rotate on its axis, those trade winds which are caused by the high pressures at the Tropic of Cancer would blow due south in the northern hemisphere. But the rotation of the earth on its axis causes them to shift to some extent. The trade winds are *northeast winds* in the northern hemisphere. We name a wind for the direction from which it comes. The trade winds blow continuously in the same direction throughout the year.

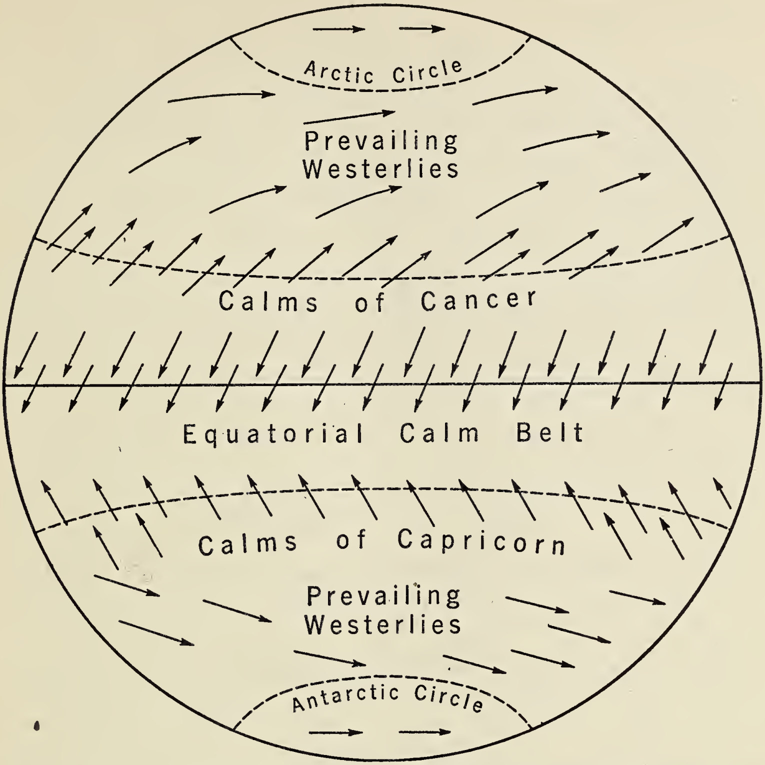


FIG. 2–11. When it is winter in the northern hemisphere the equatorial calms and the trade winds shift southward. How are the tropical calm belts affected?

South of the equator, the high-pressure areas at the Tropic of Capricorn push the winds northward toward the equator. But the rotation of the earth causes them to shift somewhat, and we have the southeast trades between the equator and the Tropic of Capricorn.

In earlier times, when sailing vessels were common, much commerce was carried along the trade-wind routes. It was easy to steer the vessels into the trade-wind areas and let them drift with the wind. You may recall that Columbus followed the trade-wind route on some of his voyages.

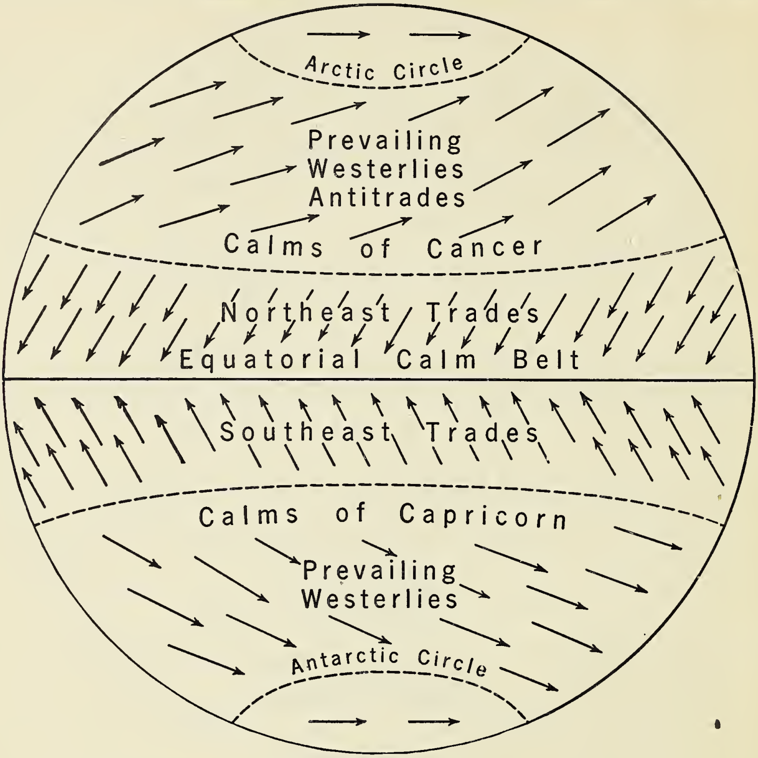


FIG. 2–12. At the beginning of both the spring and fall, we find the calm belts over the equator and the tropics. Note the position of the trade winds.

33. How do the winds blow in the North Temperate Zone? In the diagram of Figure 2–12, we see the position of the equatorial calm belt, the trade-wind zone, the calms of Cancer, and the general direction of the winds in the North Temperate Zone as they are likely to be on March twentieth or September twentieth.

The northeast trades blow constantly in the direction shown. The winds in the North Temperate Zone are called *antitrades* because they blow in a direction almost exactly opposite to that of the trade winds. The inhabitants of the United States live in the zone of the *prevailing westerlies.*

They are not so steady as the trade winds, and the direction from which they blow is not always the same.

The storms in the United States travel in a general direction from west to east, moving across the entire country in about five or six days. There is a more or less constant procession of high-pressure areas following low-pressure areas.

34. What is a "high"? The name *high* is given to an area in which the barometric pressure is relatively high. Since the pressure is high, the winds blow outward from the center of the high in all directions. [See Fig. 2–13.]

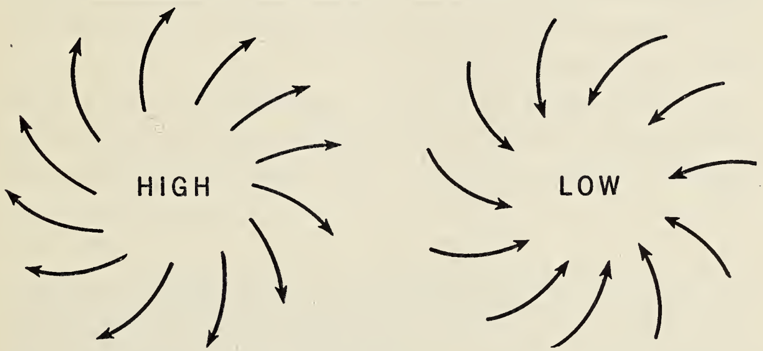


FIG. 2–13. In general, winds blow outward from high barometer areas, and toward low barometer areas. Why do they have a whirling motion?

A high-barometer area usually varies from 500 miles to 1500 miles in diameter. It moves in an easterly direction at the rate of from 400 miles to 700 miles in 24 hours. For example, a high that is central over Chicago is likely to advance as far as Cleveland or Buffalo in the next 24 hours.

As a high approaches, one may expect the temperature to drop considerably, the skies to become less cloudy, and the winds to shift to the west or the northwest. Of course the barometer rises as the high approaches. If we could get a bird's-eye view of all the high at one time, we would see that the winds, as they blow outward from the center, have a tendency to whirl or twist in a *clockwise* direction

35. What is a " low "? The name *low* is given to an area in which the barometric pressure is relatively low. The winds blow inward toward the center of such an area. If we could look down upon the entire area of a low, we should see that the winds are whirling in a counter-clockwise direction. We call such a storm a *cyclone*. The storm brought by a high is called an *anticyclone*. [See Fig. 2–13.] We must not confuse the word *cyclone* with the word *tornado*, which means a storm of great fury. We usually have two or three cyclones a week, and the winds may vary in velocity from a gentle breeze to a near-gale. The cyclone varies in width from about 500 miles to 1500 miles. Fortunately, tornadoes occur rather rarely.

As a low approaches us, we may expect to see the barometer falling, more or less rapidly. At the same time, the temperature rises decidedly. The amount of cloudiness increases, and we are likely to have rain or possibly snow. Often the wind shifts to the southwest, then south, and southeast, as the rain-bearing low comes nearer.

36. What is a " local " storm? (*a*) *Thunderstorms.* These are local storms which may vary from a few hundred feet to 15 or 20 miles in width. They develop in low-pressure areas. They occur when warm, humid air moving in from the south or southwest meets the colder air coming in from the north and west. The warm, humid air is pushed upward and patches of cumulus clouds begin to appear. Later in the afternoon, as a rule, the clouds grow larger and darker, finally developing into what are commonly called *thunderheads.*

The upper clouds expand and are cooled. Then condensation of the water vapor occurs, and the rain begins to fall, usually in large drops. As the water condenses, it sets free more heat, which warms the air and increases the uprush of the air from underneath. The upper central portion of the storm area begins to whirl, and thunder and lightning are produced. The rain now begins to fall in earnest. Such a

thunderstorm may last only a few minutes, or it may continue for two or more hours.

b) *Tornadoes.* Tornadoes develop in the southern portion of low-pressure areas, where warm humid air from the south winds meets and creeps under colder air from the west and north. As the warm air is pushed upward, the air starts to whirl around a central area of very low barometric pressure, and the winds blow with terrific force. This whirling mass of air becomes funnel-shaped, and extends from the earth to the clouds as the storm moves forward. [See Fig. 2–14.] Trees are uprooted, houses topple down, and almost everything in the path of the tornado is destroyed. Tornadoes are more common in the Mississippi Valley than in other parts of the United States. Fortunately the path of great destruction is usually only a few hundred feet in width and only a few miles long. When a tornado occurs at sea, it forms a *waterspout.*

FIG. 2–14. Tornadoes, such as the one that passed here a short time before this picture was taken, can do millions of dollars worth of damage. (*Courtesy U. S. Weather Bureau*)

*c) *Hurricanes and typhoons.* Violent storms, known as *tropical cyclones,* originate within tropical areas and move into the temperate zones. In the Pacific and Indian Oceans they are called *typhoons.* Similar storms frequently start in the Atlantic Ocean in the vicinity of the West Indies; they blow to these islands and then bend northward along the eastern coast of the United States. In the Atlantic Ocean, where they are called *hurricanes,* they occur more frequently during the fall months than at any other time. Sometimes during a hurricane, a great disturbance called a *tidal wave* is formed in the water. It moves forward with the hurricane, and the high water may destroy buildings along the low coast. Such a tidal wave destroyed most of Galveston in 1900.

A hurricane caused great destruction in the northeastern United States in the fall of 1938. Telephone and telegraph wires were torn down in New England and in some of the Middle Atlantic States. Trees were uprooted or broken off. Boats along Long Island Sound were washed up on the beach at Providence and along the shores of Connecticut and Rhode Island. The beaches were strewn with wreckage. Ocean water blown in by the wind stood at a depth of ten feet in the streets of Providence. Houses on Cape Cod and elsewhere were wrecked and even carried out to sea. The

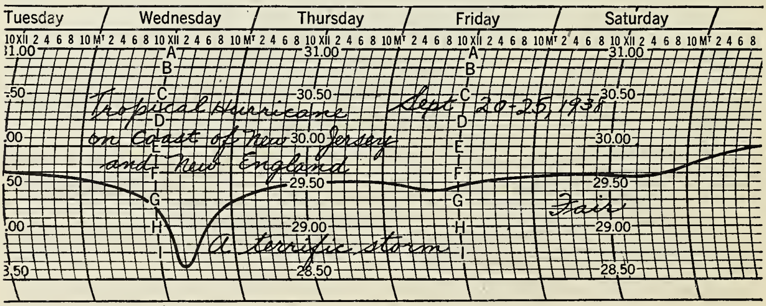


FIG. 2–15. The dip in the curve shows how sharply the barometer fell when a hurricane passed over the eastern part of the United States in September, 1938.

graph in Figure 2–15 shows the sudden dip in the barometer reading at Newark, New Jersey, as this low-pressure storm passed over the city.

37. What do weather observers do? A single reading of a barometer is of little value in foretelling weather. If you look at a barometer frequently during several hours, you can tell whether it is rising or falling. It then becomes a little more valuable for predicting the weather. But such a method is not satisfactory either. One needs to know what the readings are at other places.

The United States Weather Bureau has observers scattered all over the United States. Many of the stations are not more than fifty miles apart. What are the duties of the observers? At a certain hour of the day, normally at eight o'clock in the morning, each observer reads his instruments and consults his records to get the following facts: (*a*) the barometer reading; (*b*) the reading of the thermometer at that time, and also a reading of the lowest temperature and the highest temperature for the preceding twenty-four hours; (*c*) the direction of the wind and its velocity; (*d*) the kind of precipitation and the amount; (*e*) the state of the sky, whether clear, cloudy, or partly cloudy. All data are telegraphed to a central station to be used for making a weather map. Weather maps may be issued from airports as often as every six hours.

38. How are weather maps made? The map maker at the central office has a blank map of the United States upon which he records the data which are telegraphed to him from all the stations scattered over the entire United States. He first draws continuous lines through all those places which have the same atmospheric pressure. For example, Chicago; Davenport; St. Louis; and Lafayette, Indiana, all report pressures of 29.4 inches. They are all joined by an isobar labeled 29.4 inches. The low areas and the high areas are marked on the map. [See Fig. 2–1.]

Then a dotted line, or isotherm, may be drawn through all

places which report a temperature of 32° F. One or two other isotherms may be drawn. In winter, for example, the "zero degree" isotherm is included.

Arrows are added to show the direction of the winds, and circles are marked to show clear weather, partly cloudy weather, rain, or snow. Sometimes the map is shaded to show where precipitation is taking place.

39. How can one predict the weather? A successful weather forecaster must spend a great deal of time studying weather conditions. He must learn what kind of weather is brought by the lows or the highs. He must learn how fast the highs and lows move, and how far they travel each day. He must learn the paths which the storms usually take as they travel across the United States. [See Fig. 2–16.] For example, he must know that a low may enter the northwestern states from the Pacific Ocean; travel easterly through Montana, South Dakota, Iowa, Illinois, and Ohio; and then bend northward along the St. Lawrence River.

Suppose the weather map shows a low whose center is

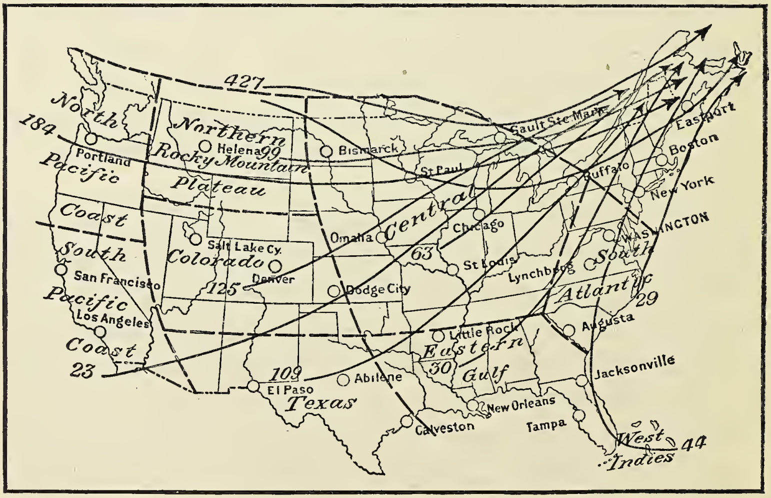


FIG. 2–16. The heavy lines, with the arrow points at one end, show well-defined paths which storms take as they cross the United States. (*Courtesy U. S. Weather Bureau*)

over Chicago. The forecaster knows the weather conditions in Chicago. What does he predict for places east of Chicago? He may expect that about twelve hours later Toledo will be having the same rainy weather that visited Chicago earlier. He predicts that the low with its stormy weather will reach Buffalo in about twenty-four hours.

Possibly the path of the storm carries it from Chicago on through Indiana, Ohio, and Pennsylvania. If this happens, the storm is likely to arrive in New York City about two days later.

Cut from cardboard two circular discs about six inches in diameter. Color one of them red and the other green. Your teacher probably has a large map of the United States which can be hung in the front of your schoolroom. From the weather map in a morning newspaper on Monday,* notice where there is a well-defined low and a well-defined high. With thumbtacks fasten the red disc on the map over the low, and the green one over the high. On Tuesday morning look at the newspaper again to see how far the high and the low have moved. Mark their new positions with the discs.

If you will do this for a week or two, you will have a better idea of the manner in which storms move across the United States, or the paths they travel, and the speeds at which they move.

40. Why do forecasters make mistakes? Alexander Pope wrote, "To err is human, to forgive divine." Weather forecasters are human and make some mistakes. You have probably heard some persons say, "The weather man is more often wrong than he is right." Such a statement is untrue, for the passing mark for a forecaster is about 80 per cent. Unless he is correct 80 per cent of the time, he is likely to lose his position. There are several reasons why a forecaster cannot be correct all the time:

* If weather maps do not appear in current newspapers, try to secure back numbers from a library or from a newspaper office.

a) *A storm may change its path.* A storm which leaves Chicago, for example, and appears to be moving on to New York, may suddenly change its path and travel up the St. Lawrence Valley or possibly southward through Virginia. If it misses us, we forgive the forecaster his mistake.

b) *A storm may change its speed.* Perhaps a certain storm has been traveling an average of 400 miles per day. For no apparent reason, it may remain in one place for twenty-four hours or more, with little or no forward motion. Then the storm predicted by the forecaster arrives a day late. It may also happen that a storm which has been traveling at an average speed of 400 miles a day for two or three days suddenly increases its speed to 700 miles per day. Then the storm arrives from fifteen to twenty hours earlier than had been predicted. We are not so likely to forgive the forecaster for this mistake, especially if it spoils a picnic or a baseball game for us.

c) *A storm may die out, or lose its vigor.* There may be a very severe storm raging over Iowa or South Dakota. The weather forecaster may warn the eastern coast states of an approaching storm of great severity. But by the time it arrives at the eastern states, two or three days later, the storm may have lost most of its vigor.

d) *A storm may increase in vigor.* The day before the inauguration of William Howard Taft as President, the official weather map showed no storm in sight. The forecaster predicted fair weather for the inauguration. But a small, low-barometer area over Texas suddenly began to increase in vigor. It raced up toward Washington at unusual speed. It struck that city as a raging fury. Instead of the fair weather that had been promised by the weather man, Washington suffered one of the most severe snowstorms in its history. That unfortunate error of a forecaster is still remembered.

e) *Do you understand the forecaster's terms?* Possibly you have heard someone say: " The weather man predicted

fair weather for today. Look at all those clouds." In the language of the forecaster, the term *clear* means that less than 30 per cent of the sky will be cloudy; the word *fair* means that from 30 per cent to 70 per cent of the sky will be cloudy.

A prediction of local thundershowers may be made for an area with a radius of about 50 miles. One place within that area may have the thundershowers and another place a few miles away may not get them, but the persons in that area should not blame the forecaster. His prediction was correct.

41. Of what value is weather forecasting? If the Weather Bureau predicts a severe gale along the Atlantic Coast or the Gulf of Mexico, small coastwise vessels take the warning and remain in the harbor. Hundreds of thousands of dollars are saved annually by the shipping industry as a result of storm warnings.

A farmer cuts grass for making hay on one day, and usually permits it to dry in the sun until the next day. If it rains when the hay is fairly well dried, or *cured*, the hay will be

Fig. 2–17. In normal times, the Weather Bureau's warning of cold weather would enable the fruit grower to start fires in smudge burners to protect his fruit. (*Courtesy Burgert Bros.*)

of poorer quality, since it will be darker and more dusty. Therefore when a farmer hears over his radio that rain is predicted for the following day, he does not mow his grass.

Predictions of early frosts sometimes save fruit growers thousands of dollars. After the warning, they may pick the fruit that is ripe enough, or they may build smudge fires in the orchards to protect the fruit from frost. [See Fig. 2–17.]

Nearly every first-class airport has its own weather observers. In addition to the data ordinarily used for forecasting, such stations also include *visibility* and *height of ceiling*. If the report shows the visibility to be one mile, that means that an aviator can see for a distance of one mile, horizontally, from the landing field. If the report shows that the ceiling is 3000 feet, that means that an aviator can see the ground below him if he is at an elevation of 3000 feet or less. The expression *zero-zero* means that the fog and mist are so thick that the height from which an aviator can see the ground is zero feet, and the distance he can see in a horizontal direction is also zero feet. When an airport broadcasts the fact that the weather conditions are zero-zero, then an incoming aviator seeks a field where he can land more safely. If he takes off from such a field, he must be prepared to do some *blind* flying. That means that the aviator must depend entirely upon his instruments to keep him on his route. He cannot judge by glimpses of familiar landmarks.

42. What is humidity? Weather reports frequently give the percentage of *humidity* in the air. When we speak of humidity, we mean the moisture, or the water vapor, which is present in the air. The amount of moisture present in the air varies considerably in different places, and also in the same place at different times. Even in desert regions there is some moisture present in the air at all times.

43. What is capacity? The amount of moisture that the air can hold at any given temperature is called its *capacity*. If 1 cubic foot of air, for example, can hold 12 grains of water vapor at a certain temperature (there are 7000 grains

in one pound), we say the air has a capacity of 12 grains per cubic foot. The amount of water vapor which the air can hold increases as the temperature increases. It has been found by experiment that 1 cubic foot of air at 32° F. can hold just a trifle more than 2 grains of moisture. In the same manner, it is found that 1 cubic foot of air at 100° F. can actually hold 20 grains of water vapor. If *saturated* air (air holding all the moisture that it can hold) at 100° F. is cooled to 32° F., each cubic foot of such air will lose about 18 grains of water vapor.

44. What do we mean by absolute humidity? We have a tin measure which holds one quart. In that measure we place one pint of water. The capacity of that measure, or what it *can* hold, is one quart. What it actually *does* hold is one pint. In a similar manner, the air at a certain temperature can hold 12 grains of water vapor per cubic foot; but possibly we find that it does hold at a given time only 6 grains of water vapor per cubic foot. The amount of moisture that the air does contain is called its *absolute humidity*. Of course the air does not always hold all the moisture that it can hold. In other words, it is not always saturated.

45. What is meant by relative humidity? If a quart measure has in it only one pint of water, it is only 50-per-cent full. If air which can contain 12 grains per cubic foot does contain only 6 grains per cubic foot, then it is only half saturated, or it is 50-per-cent full of moisture. The *relative humidity* of the air is the relation between the absolute humidity (what it does contain) and the capacity (what it can contain). In the example given, the relative humidity of the air is 50 per cent. Relative humidity is expressed in per cent.

Our comfort depends upon relative humidity. In summer we feel hot and sticky when the relative humidity is high, because the perspiration from our skin evaporates so slowly. In the winter we feel uncomfortable in a room in which the relative humidity is too low. The air feels too dry. Perspira-

tion evaporates too rapidly, and we feel chilly, even in a room that is 68° F. or even 70° F. For our comfort, the relative humidity should be from 40 per cent to 60 per cent.

It is important for you to remember that warming the air in a room *decreases* the relative humidity, because it increases the capacity of the air. Cooling the air in a room *increases* the relative humidity, because it decreases the capacity of the air. A cold room in winter may feel damp, but the dampness disappears as a fire warms the room.

46. What causes precipitation? We may think of the air, as it takes up moisture by evaporation, as being similar to a huge sponge which soaks up water. If we squeeze the sponge, water will drip from it. If we cool the air, it will lose some of its moisture, too. The harder we squeeze the sponge, the more of its moisture will it lose. The more we cool the air, the more moisture will drip from it.

47. In what form does precipitation occur? The manner in which the moisture of the air *condenses* may vary a great deal. We may consider the following forms of precipitation:

a) *Dew and frost.* We permit a glass of ice water to stand in a room on a warm summer day. As the warm air comes into contact with the cold walls of the glass, it loses some of its moisture in the form of drops of liquid water. The air has been cooled until some of its moisture begins to condense. The temperature at which such condensation of moisture begins is called the *dew point.* We call moisture deposited in such manner *dew.* At night, grass and other objects on the surface of the earth may cool off rapidly. Then dew is deposited upon such objects by the surrounding air which is chilled below the dew point as it comes into contact with them.

If the dew point of the air is 32° F., or even colder, then the moisture of the air which is condensed by coming into contact with cold objects is deposited in the form of small ice crystals known as *frost.*

b) *Fog and cloud.* When we see our breath on a cold

winter morning, we really see a tiny *fog* which is formed by the intermingling of the warm moist air of our breath with the cold air around us. The cold air condenses the vapor in drops so small that they float in the air. Sometimes the air in valleys or over lakes may be chilled to its dew point. Then some of its moisture will condense upon tiny dust particles that are always present in the air, and thus form a fog. An iceberg which floats southward into the Atlantic Ocean is frequently surrounded by fog. Can you explain why?

Some *clouds* consist merely of fog, but they are formed at higher elevations. They are formed when warm, moist air is cooled until its moisture begins to condense. Some high clouds, which are formed where the temperature is below the freezing point, are composed of particles of snow and ice. They are mostly *cirrus* clouds. Clouds vary greatly in shape and appearance. Some of them are particularly beautiful as they float in the sky or are driven about by the winds.

c) *Rain and snow.* Before *rain* can fall, the air must be cooled below the dew point. Clouds appear. When the tiny drops of moisture grow large enough by further condensation of water vapor, then rain falls in drops. In the next

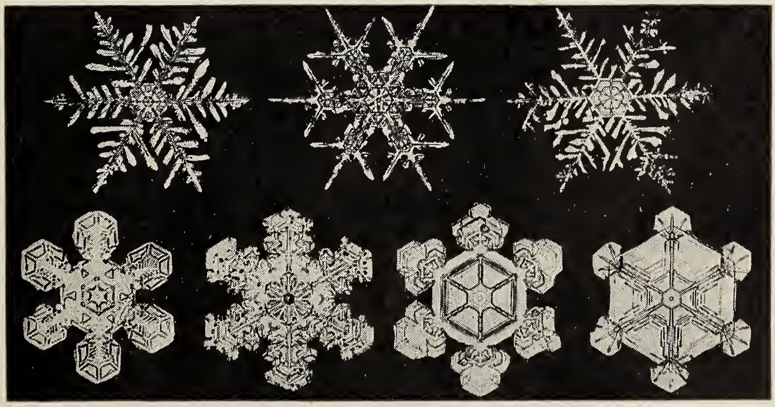


FIG. 2–18. Each snowflake has a highly complicated, beautiful pattern. These few examples suggest the variety in the design. How could you examine snowflakes? (*Courtesy U. S. Weather Bureau*)

chapter we shall discuss some of the ways in which air is cooled enough to cause rain.

If water vapor condenses to form clouds when the temperature is below the freezing point, then *snow* falls. Snowflake crystals vary in shape, and thousands of different forms have been studied. Most of them are six-sided figures. [See Fig. 2–18.] W. A. Bentley made the photographing of snow crystals his hobby. Over 2000 different shapes are shown in the book entitled *Snow Crystals* by Bentley and Humphreys.

d) *Sleet and hail.* Sometimes falling rain passes through cold layers of air. If some of the raindrops freeze, they fall as *sleet*. It is possible, too, for snowflakes partially to melt, and then freeze again to form sleet. Ice storms are caused by the freezing of rain as it falls upon some object which is colder than the freezing point. In such storms the pavements and sidewalks may become completely glazed, and the telephone wires and the branches of the trees may be encased in an icy coat of mail.

Hail is not frozen rain. If you place a large hailstone upon a stove until it is half melted, you will see that it is made up of layers of snow and ice. Whirling air currents may throw a drop of water, or a flake of snow, into alternate layers of warm air and cold air, in this way forming successive layers of snow and ice, or of ice and snow. The hailstones may be held up by rising air currents until they finally become heavy enough to fall to the ground.

Questions

1. What do we mean when we say that the weather is fickle?

2. Do you think that the weather predictions that are given in the almanacs are either scientific or accurate? What is the scientific method that you should pursue to be certain of your answer?

3. Does a barometer rise or fall when carried down into a deep mine? Does it rise or fall when it is carried to the top of a high mountain?

4. Would you expect a barometer to rise or to fall if it were carried into a steam-filled room?

5. Does high temperature or low temperature usually accompany high barometer readings?

6. What is an *altimeter?*

7. It is not strictly correct to say that warm air "rises." How would you express it more accurately?

8. Why are icebergs usually surrounded by fog?

9. When the humidity is high, some persons say that the air is "heavy." Since moist air is actually less dense than dry air, what do they mean?

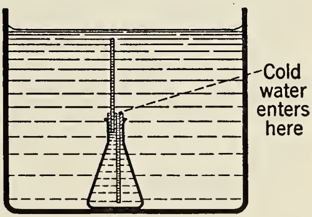
10. A cold room may seem damp. If a fire is started in the room, the air will soon feel dry. Why does it?

11. How does a hurricane differ from a cyclone?

SOME THINGS FOR YOU TO DO

1. Perform for yourself the class demonstration suggested in section 46. [See Fig. 2–19.]

FIG. 2–19. The colored solution in the flask is much hotter than the water in which the flask is submerged. The dense cold water enters through one tube and pushes the solution out of the flask through the other.



2. If an aneroid barometer is available, read it carefully on the ground floor of your school building. Then carry it to the top floor and read it again. Does it show a difference? If so, how much?

3. Use a blank map of the United States. Ask your instructor to give you a set of data showing temperature and barometer readings at various places. Draw the isobars and isotherms. Show by arrows in what directions you expect to find the winds blowing. Show the condition of the sky, and mark the places where precipitation of some kind is probable.

THINK ABOUT THESE!

1. Why may you say that the climate of a place is steady but that the weather is changeable?

2. Do ocean currents have any effect upon the climate of a place?

3. Do you think that mountain ranges have any effect upon the climate of places near them?

WORDS FOR THIS CHAPTER

Oceanic (ō′shē·ăn′ĭk) **climate.** A climate which is not subject to extremes of temperature.

Continental climate. A climate which is subject to extremes of temperature.

Torrid Zone. The belt of the earth between the Tropics of Cancer and Capricorn.

Drift. A movement in the ocean, slower than a current.

Tempered. Moderated.

Fiord (fyôrd). A narrow inlet of the sea, walled by steep rocks. Most common in Norway and Alaska.

Savannas. Treeless belts of grassy plains which have a hot, dry season and a rainy season.

Compression. The process of reducing the volume of something by squeezing it.

CHAPTER 3 ——————— *UNIT 2*

What Makes Climate?

48. How is climate related to weather? Suppose you have a poor lesson on one day; would you like to have your teacher rate you as a poor student? It would not be fair, either, to rate you as an excellent student, if you happen to have a perfect lesson on only two or three days in one term. You are likely to be rated on the average of what you do from day to day.

Suppose you live where the temperature rises to 100° F. on three successive days in July, and falls to 10° F. below zero on three successive days in February. In one case you would say, "We are having a hot spell of weather," and in the other case, "We are having a cold wave." You would not say that you live in a hot climate or in a cold climate. The climate of the place in which you live is based upon the average weather conditions of a period of several years. The average amount of rainfall, too, helps to determine the climate, but we do not describe the climate of a place as being *wet* because we have a few days of rainy weather, or as being *dry* because it has not rained for a couple of weeks.

How do climates differ? Siberia, we say, has a cold climate. The temperature of northern Siberia may fall to 70° F. below zero in winter, but it may get rather warm in the summer. Places within the tropics are likely to be hot the year around, unless their altitude is high. The climate of southern Nevada or of the Sahara is said to be dry, but a place in the Amazon River Valley is said to have a wet climate. All these terms are used in a relative sense.

San Francisco and Honolulu have *oceanic climates.* Such places are not likely to have very cold weather in winter, or very hot weather in summer. Their climate is tempered by the ocean, whose waters warm slowly and cool slowly. [See Fig. 3–1.]

The city of St. Louis has a climate which is subject to extremes of temperature and is therefore called a *continental climate.* The temperature may fall to 20° F. below zero in winter, and rise above 100° F. in summer. [See Fig. 3–2.]

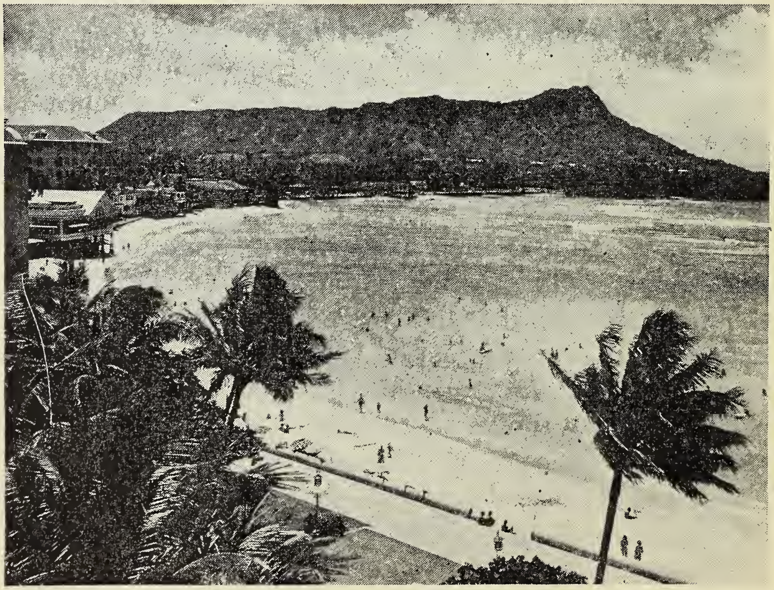


FIG. 3–1. Winds blowing along the shore at Waikiki are unlikely to become cold. (*Courtesy Pan Pacific Press Bureau*)

Fig. 3–2. Winter in a continental climate has its good points. (*Suppenmoser from Monkmeyer*)

49. Why does a large body of water make a climate moderate? It is an interesting fact which can be proved in the laboratory that it takes more calories of heat to warm one pound of water one degree than it does to warm one pound of any other common substance one degree. For example, iron warms about nine times as fast as water does. Water not only warms slowly, but it also cools slowly. We make use of this fact when we put a hot-water bottle at the feet of a sick person. Water has a high heat capacity.

There are several other reasons why the sea heats more slowly than the land. (*a*) The sun's rays penetrate the water to a much greater depth than they penetrate the soil. Therefore, it is necessary that more of the material in any given area be warmed. (*b*) The soil is dark-colored,

and it absorbs the heat rays from the sun. The water is a better mirror than the land, and it reflects much of the sun's heat rays. (*c*) The soil is at rest. The ocean waters are almost constantly in motion. When one portion of the water is heated, other cooler portions may come rolling in to take its place.

The effect of water upon the climate of a place near the water is most important, and we must keep in mind the several reasons which explain why *water warms more slowly and cools more slowly* than land does.

50. How do the climates of San Francisco and New York City compare? Over a period of thirty years, the lowest temperature ever recorded in San Francisco was 29° F. The average temperature for the coldest month, December, is 50° F. In New York City the temperature in winter sometimes falls to 0° F., or even below. The average temperature for the coldest month is about 34° F.

The highest temperature in San Francisco may reach 100° F., but the average temperature for the hottest month is 63° F. In New York City, the highest temperature occasionally reaches 100° F., but the average temperature for the hottest month is about 75° F.

New York City is near the ocean; San Francisco is on the ocean. New York City is a little farther north than San Francisco. Why does San Francisco have an oceanic climate, while New York City has a continental climate, which is subject to great extremes in temperature? Both are in the zone of prevailing westerly winds. But San Francisco receives the winds which have been moderated as they blow across the Pacific Ocean. Such winds are warmer in winter than the land, and cooler in summer. New York receives the winds which have blown across the land areas of the United States, and they are often intensely heated in summer and extremely chilled in winter.

What do we conclude? (*a*) A place situated on or near the ocean may have an oceanic climate. That is true for

places in the zone of westerly winds, provided those places are on the *western* coast. It applies to such cities as Seattle, Portland, San Francisco, and Los Angeles. It applies also to the western coast of Europe. (*b*) A place may be situated on or near the ocean and still not have an oceanic climate. That is true for places in the zone of westerly winds, provided those places are on the *eastern* coast of the continent. This applies to Boston, Providence, and New York; and, to some extent, to Philadelphia and Washington.

51. What causes land breezes and sea breezes? We have learned that the land warms more quickly than the water, and that it cools more quickly. On a hot day in summer, the land along the shore of the ocean heats quickly in the morning. The air above the land is heated. As it is warmed, it expands and becomes less dense. Then it is pushed upward by the colder, denser air coming in from over the ocean. [See Fig. 3–3.] For places along the Atlantic Coast, a sea breeze from the ocean begins to blow at about 10:00 o'clock on a summer morning and continues to blow until late in the evening.

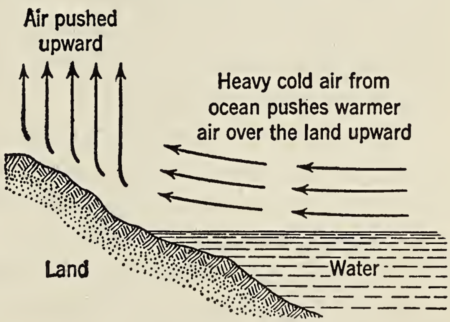


FIG. 3–3. On a hot day the air above the land is heated and becomes lighter. Colder, denser air from the water moves in and pushes the warmer air upward.

At night the land cools off more quickly than does the water. The air above the water is warmer than that above the land. It expands and becomes less dense. Then colder air from the land blows toward the ocean. [See Fig. 3–4.] The land breeze begins to blow toward the ocean about mid-

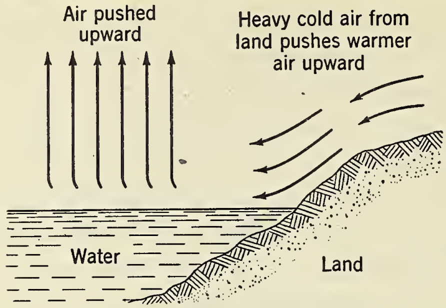


FIG. 3–4. The land cools more quickly than the water. At night the colder, denser air from above the land pushes upward the warmer, lighter air above the water.

night. Many fishermen in small sailing boats go to sea about midnight, sailing with the land breeze; they return in the middle of the forenoon, sailing with the sea breeze.

*52. **What are monsoons?** A huge *seasonal* land and sea breeze is known as a *monsoon*. The monsoons of India are best known, although monsoons may occur at other places. In the summer, the tropical sun heats the land areas of India until they become much hotter than the waters of the Indian Ocean. The land cools off very little at night. Therefore from about the first of May until the first of October, the winds blow steadily from the ocean toward the land, producing one steady *sea breeze*.

For about one month, the land and water are of approximately equal temperature; then the winds become variable and may blow in any direction. After that, the temperature of the air above the *land* falls below that of the air above the *ocean*, and the wind begins to blow steadily toward the ocean. This huge *land breeze* lasts for a period of about five months.

53. **What are ocean currents?** You are familiar with streams and rivers which flow over the land. Do you think it is possible for a river or stream of water to flow through the ocean? There are some large streams of water which are always flowing through the ocean. We call them *ocean currents*. They may vary from twenty miles to more than one hundred miles in width, and some of them are thousands of miles long. Some of them are warm streams, others cold.

*54. **What causes ocean currents?** At one time men thought that the unequal heating of the water of the ocean was the chief cause of ocean currents. Scientists still think that that may be one of the minor causes. But years ago one man was doubtful. He believed that winds are the chief cause of ocean currents. Because he was a true scientist, he decided to experiment. He built clay models of the continents and filled the spaces between with water. Then he set up bellows at various places to produce breezes to correspond to the trade winds and the prevailing westerlies. He succeeded in producing, on a small scale, currents that flowed in about the same direction in which the ocean currents actually flow. This experiment furnished proof that winds help, at least, to cause ocean currents.

It is fairly certain, too, that the counter currents along the equator are caused by the rotation of the earth on its axis.

55. **What are some of the important ocean currents?** (*a*) *In the Atlantic Ocean.* Let us look at the map in Figure 3–5. In the Atlantic Ocean, the *North Equatorial Current,* which is believed by some to be set up by the northeast trade winds, flows in a westerly direction through the tropical waters in the northern part of the *Torrid Zone.* South of the equator, we find the *South Equatorial Current* flowing westward from the coast of Africa to the eastern coast of South America. At the point of land called Cape St. Roque, it divides. The southern portion flows southward and forms the *Brazilian Current,* which flows along the Brazilian coast. In the region of the prevailing westerlies of the southern hemisphere, the Brazilian Current is deflected and flows eastward. The northern half of the South Equatorial Current flows northward across the equator and joins the North Equatorial Current in the Caribbean Sea and the Gulf of Mexico to form the well-known *Gulf Stream.* In the zone of the prevailing westerlies, the Gulf Stream bends eastward and flows across the Atlantic Ocean. At the Cape Verde Islands it divides, a portion flowing southward, and the other

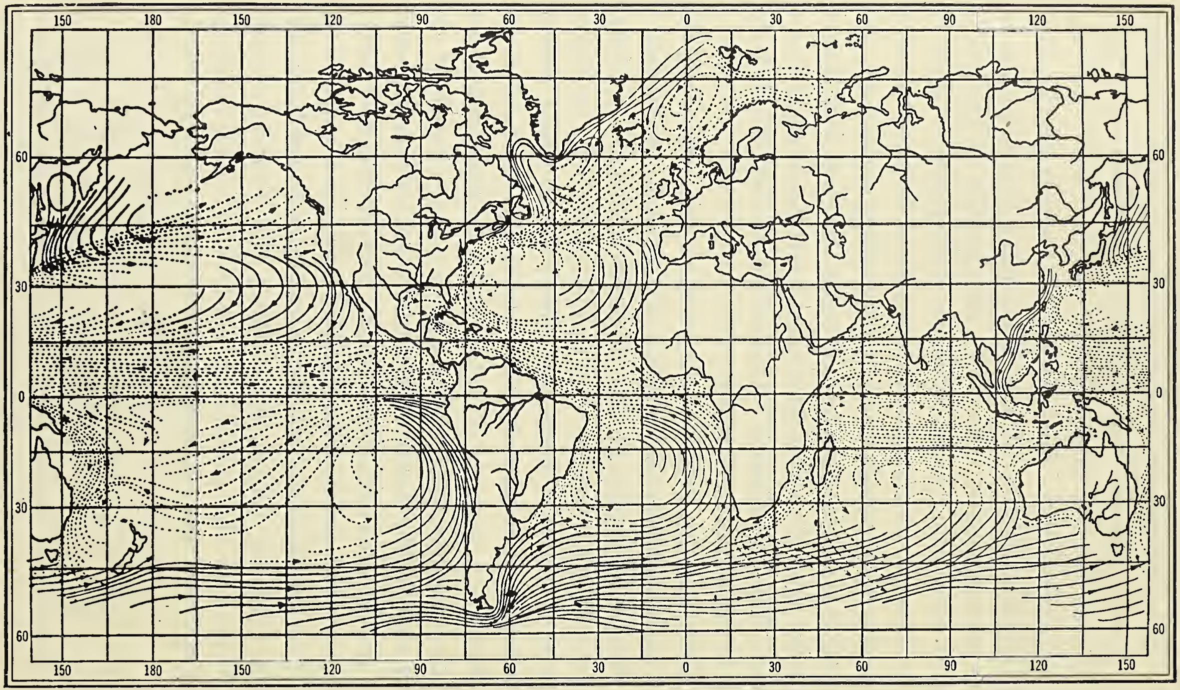


Fig. 3–5. The lines and arrows show the paths through which ocean currents move. Why is England warmer than Labrador? Can you pick out the cold currents and the warm ones?

portion flowing northward past the British Isles and on to the coast of Norway. These are all *warm currents.*

From the Arctic Ocean we have the cold *Labrador Current* flowing south past the coasts of Labrador and Newfoundland. When the South Equatorial Current begins to flow eastward, it joins with the cold waters of the *Antarctic Drift.* A cold current from this drift flows northward along the southwestern coast of Africa.

b) *In the Pacific Ocean.* In this ocean, too, we have both a *North Equatorial Current* and a *South Equatorial Current.* The South Equatorial Current bends southward at the coast of Australia and forms the East Australian Current. At the coast of China, the North Equatorial Current bends northward and forms the *Japan Current.* This current flows past the coast of Japan and then bends eastward toward the coast of Alaska, Canada, and the northwestern states of the United States. These are *warm* currents. [See Fig. 3–5.]

56. How do ocean currents affect climate? When you look at a map of the world, you will see that England is about as far north as Labrador. How do the climates of the two compare? In Labrador the lakes and streams are frozen from October to June, and the temperature sometimes falls to 60° F. below zero in winter. The average temperature of the short summer is 55° F. In London the average temperature for the entire year is about 50° F., and the average temperature for the winter months is about 40° F. How do we explain the differences in temperature in England and in Labrador? The reasons follow:

a) The *cold* westerly winds which Labrador receives have blown across the entire width of Canada. The rather *warm* winds which England receives have been *tempered* by the waters of the Atlantic Ocean.

b) The cold Labrador Current from the Arctic Ocean flows down past the shores of Labrador. The warmer waters of the Gulf Stream flow near the coast of England.

The coast of Alaska, too, has a moderate climate because

FIG. 3–6. The Gulf Stream helps to temper the climate along the west coast of Norway. The fiords along this coast do not freeze. (*Monkmeyer*)

it is warmed by the waters of the Pacific Ocean and the rather warm waters of the Japan Current. Sitka, Alaska, is about 700 miles farther north than the city of Quebec. In Sitka, the temperature in August ranges from 35° to 87° F., and the average annual temperature is 43° F., about the same as that of Oslo, Norway. In Quebec, heavy snows cover the ground from November to April; and the winter temperature is severe.

Norway, the land of the midnight sun, extends about 300 miles north of the Arctic Circle. Its *fiords* on the west coast do not freeze in winter, because the entire west coast is tempered by the westerly winds from the Atlantic Ocean and from the Gulf Stream. The winters along the coast are mild, and the summers are cool. Barley, rye, oats, and potatoes are grown as far north as the Trondheim Fiord, only about 200 miles from the Arctic Circle. [See Fig. 3–6.]

57. How does altitude affect climate? The effect of altitude upon the temperature of a place is important. Mexico gives us a good example. In the lowlands of Mexico, in the

cities of Veracruz (vā′rä·kro͞os′), Acapulco (ä′kä·po͞ol′kō), or La Paz (lä päs′), we find what are called the *hot lands.* In such cities the average annual temperature is about 80° F. It seldom falls below 60° F., but it often rises above 100° F.

Above the *hot lowlands* we have the *temperate lands* which have an elevation of from 3000 to 6000 feet above sea level. The average temperature is about 65°, and it never varies more than 4 or 5 degrees during the entire year. Therefore extremes of temperature are unknown in these regions.

At an elevation of 7000 feet or more, we have the so-called *cold lands.* The average temperature at such elevations is about 60° F., although some of these lands lie south of the Tropic of Cancer and are in the Torrid Zone.

Along the coast of Mexico, and at elevations up to 2500 feet, such tropical fruits as oranges, lemons, bananas, and coconuts are grown. If you go up from the lowlands, you

FIG. 3–7. Oranges grow in some parts of our country. Where do our bananas come from? (*Courtesy Florida Citrus Commission*)

will find the fruits and grains of the temperate zones. At still higher elevations, you will find the hardy plants of the Arctic regions. [See Fig. 3–7.]

Mexico City is more than 7000 feet above sea level. It has a moderate rainfall of about 20 inches per year. Although it is about 250 miles south of the Tropic of Cancer, its average temperature during the summer months varies from 60° F. to 65° F., and the temperature in winter does not vary more than 12° or 15° from the summer temperature.

58. What factors determine the amount of rainfall in a place? There are at least three things that are necessary if a place is to have abundant rainfall. (*a*) There must be a large water area from which evaporation can be taking place almost all the time. (*b*) There must be some method of carrying the moisture-laden air to the place itself. (*c*) There must be some method of cooling the moisture present in the air, in order to cause its precipitation as rain, snow, or sleet.

59. What is the source of the water in the air? In our study of the water cycle, we learned that water is evaporating at almost all times from the ocean, the lakes, and the rivers. Water is given off to the air, too, by plants which take in water from the soil through the roots and give it off to the air through their leaves. The amount given off in this manner is much more than one would suppose. An acre of grass will give off to the air from 2 to 6 tons of water in twenty-four hours, if the weather is hot and dry. Animals, too, give moisture to the air as they breathe.

Evaporation is much more rapid in warm weather than it is in cold weather. It increases, too, when the winds blow over the surface of the liquid from which evaporation occurs. Evaporation occurs more rapidly when the amount of moisture in the air is very small, or when the humidity is low. It is easy to understand, too, that more water will evaporate from a broad expanse of water, like the ocean, than from a small lake.

60. How is the moisture of the air carried? Upon some sleepy summer day, you may lie on the grass, gazing into the blue sky above, idly watching the clouds drifting by. Possibly some of them are light, fleecy clouds high up in the air. Some of them may be more like sacks of wool. Or at another time, you may see patches of darker clouds go scudding along as if they were in a hurry to reach some destination.

In all such cases, the clouds are carried along by the winds. We must remember that wind is air in motion. If the winds carry the moisture-laden air to a place, then that place may have abundant rainfall. But if they carry the air *away* from a place, the possibilities of rainfall are much smaller. How much rainfall do you think India can have during the five months when the winds are blowing from the lands toward the Indian Ocean?

The Great Basin in the western part of the United States is surrounded by a wall of high mountains. Would you expect much rain to fall there? The average annual rainfall for the state of Nevada, which lies in the Great Basin, is less than ten inches. Some valleys are almost rainless.

61. What causes precipitation? Above a certain place, the winds may be carrying clouds loaded with moisture, but even then it may not rain. *It cannot rain unless the air is cooled in order to condense some of its vapor into drops of liquid water.* What are some of the ways in which the air may be cooled?

a) The air may be cooled as it rises. This happens because the temperature grows colder at higher altitudes; also because the air expands as it rises, and the expansion of the air produces a cooling effect.

b) The land may be colder than the ocean. Then the winds blowing from the ocean will be cooled as they blow across the land areas. This is particularly common in winter, at Los Angeles, for example.

c) Masses of warm, moisture-laden air may be cooled by being mixed with colder air blowing in from another region.

*62. **Where is the zone of daily afternoon rains?** In the equatorial calm belt, the heat from the *direct rays of the sun* is terrific. The moist air which is heated by the sun expands and is pushed upward by the trade winds blowing toward the equator. The expansion of the air, aided by the higher altitude, causes a cooling effect. It rains almost every day, particularly in the afternoon. The total amount of annual rainfall in such regions may reach 200 or more inches. That means that if the ground were level, and all the rain for one year fell at one time, the ground would be covered with water to a depth of 200 inches, or more than 16 feet. [See Fig. 3–8.]

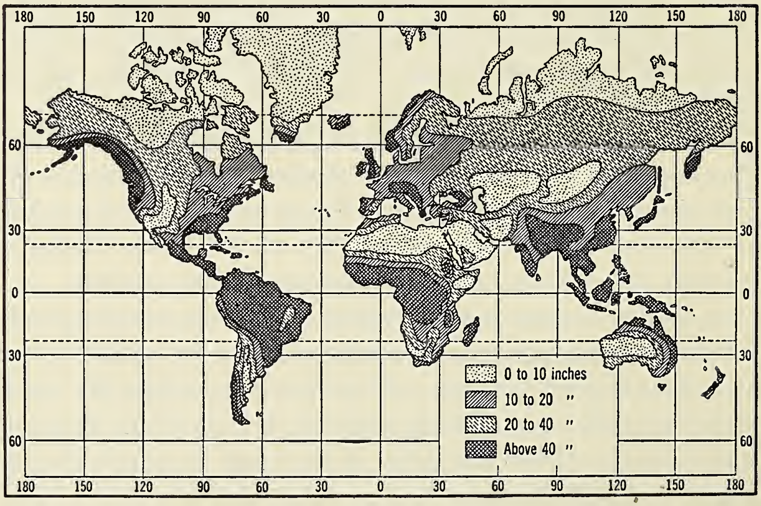


Fig. 3–8. A rainfall map of the world. For farming, about 20 inches of rain are needed. What areas have that much rain?

In such regions, tropical plants grow thickly. Forests are so dense, and the trees are so much entwined with vines, that it is difficult for man to make his way through the forests. In this hot, humid climate, winds are almost entirely absent, and the night temperature is only from 4° F. to 6° F. cooler than the temperature in the daytime. In the days of sailing vessels, sailors frequently became marooned in this calm belt, which they called the *doldrums* (dŏl′drŭmz).

63. What are the savannas? In our summer, the direct rays of the sun move north of the equator. Of course the calm belt with its heavy rains moves northward with them. That means that the region extending a few degrees north of the equator has one hot, rainy season lasting a few months.

Then when we have winter in the northern hemisphere, the direct rays of the sun will be shining on those places south of the equator, and a belt south of the equator will be hot and rainy. What will be happening in the belt north of the equator which had its rainy season during our summer? It will now be parched and dry. Those regions which extend for a few degrees north and south of the equator are called *savannas.* They have a *dry season and a rainy season.* There are almost no trees growing in the savannas, because they cannot live through the months of drought. But the savannas are covered with grass which grows luxuriantly during the rainy season and is able to survive the season of drought. For that reason the savannas afford some of the best grazing lands in the world. In Australia they are called the *downs;* in Venezuela they are known

FIG. 3–9. The downs of Australia provide excellent grazing for sheep. (*Courtesy Australian News and Information Bureau*)

as the *llanos;* in Africa they are called the *park lands;* in Argentina they are called the *pampas;* and in Brazil they are called the *campos.* [See Fig. 3–9.]

64. Why do the calms of Cancer and Capricorn produce arid, or desert, regions? If you look at a map of the world, you will observe that the Tropic of Cancer passes through the arid regions of Mexico, the desert of Sahara, and the desert of Arabia. You will notice, too, that the Tropic of Capricorn passes through the arid regions of Australia, the desert of South Africa, and the desert of northern Chile.

You will recall that the air currents are *descending* in the calm belts of the tropics. As the air descends, it is compressed. Compressing air increases its temperature, and *it can never rain while the air is being warmed.* These conditions apply especially to spring and fall.

Places situated at or near the tropics do have some rain during those periods when the calms of the tropics shift with the movements of the equatorial calm belt. The rain under such circumstances may be carried to them either by the prevailing westerlies or by the trade winds. Let us take southwestern Australia as an example. During their winter season the calms of Capricorn have moved northward and the westerlies carry moisture-laden air toward the land. It is cooled, and the rainfall at that season is sufficient for the growth of vegetation.

65. How does rainfall vary in the United States? The western parts of Washington and Oregon have plenty of rainfall, but the eastern portions of these two states have little rainfall. As the air rises to pass over the high Cascade Mountain Range west of the central parts of those states, it is cooled and loses its moisture upon the *western slopes* of the mountains and in the valleys to the westward. As the air currents descend on the eastern slopes of the mountains, they are being warmed by *compression,* and there is little rainfall.

The Sierra Nevadas on the eastern boundary of Califor-

nia are like the Cascade Range farther north. On the western slopes of the mountain and through the Central Valley of California rainfall is plentiful. The coast of southern California has some rainfall in winter when the land is enough cooler than the Pacific Ocean to cause some of the moisture from the westerly winds to be condensed.

We have already learned why the Great Basin, ringed about with tall mountains, has little rainfall. It includes large portions of Utah, Nevada, and Arizona.

As the winds pass up over the Rocky Mountains, rain falls on their western slopes. East of the Rockies we have the Great Plains, where the rainfall varies from 10 to 20 inches per year. They are somewhat like the savannas, and some kinds of grass and alfalfa grow in sufficient quantities to make excellent grazing lands.

Farther east, in the Mississippi Valley, the whirling cyclonic storms pick up moisture from the Gulf of Mexico. As they move onward toward the east, or sometimes toward the northeast, they mix with colder air coming in from Canada. Then precipitation occurs. In this region of the Mississippi Valley the rainfall varies from 30 inches to 60 inches annually. Here we have some of the best farming areas in the United States.

The moisture which supplies the Appalachian Highlands and the eastern states with rainfall comes largely from the Gulf of Mexico and from the Atlantic Ocean. In these states the rainfall amounts to from 30 to 50 inches annually.

Questions

1. Why does it rain nearly every afternoon in the regions of the equatorial calm belt?
2. Why does so little rain fall in the regions of the tropical calm belts?
3. Why does the state of Nevada have so little rainfall?
4. Why is Sitka, Alaska, such a rainy place?

5. How do you explain the fact that Arabia is a desert region?

6. What part of western Australia will have rainfall when the calms of Capricorn move northward?

7. Can it ever rain while the air is being warmed? Explain your answer.

8. Why is frost more likely to occur during a clear night than during a cloudy night?

9. Why is frost less likely to occur during a windy night than during a calm night?

10. Is the climate of Washington, D. C., oceanic or continental?

11. Does Seattle, Washington, have an oceanic climate or a continental climate? Explain why.

12. Why does Honolulu have an oceanic climate?

13. What kind of climate would you expect Minneapolis and St. Paul to have? Give reasons for your answer.

14. Why do many fishermen along the North Atlantic coast go to sea about midnight?

Something for you to do

Write a short letter to someone (imaginary or real) in South America to describe the kind of climate in which you live.

We Need Heat Energy and Protection from It

WHEN the weather is bitterly cold, you may rub your hands together to warm them. Such rubbing brings more blood to the surface of the skin, and it also helps to warm your hands by friction. Did you ever use a saw to cut off a plank? If so, you probably found that the saw was decidedly warm when you had finished the work. What caused this heat?

You know some of the effects that heat produces. You know that heating a substance raises its temperature. You know that heat can melt ice or cause water to boil away and pass off into the air in the form of water vapor. In your study of climate, you learned that heating a gas or a liquid will cause it to expand. Solids, too, expand when they have been heated.

In Unit 3 you will learn how man uses heat energy to do some of his work for him. You will read how he needs to protect himself from cold or from too great heat by wear-

ing clothing, and how he uses heat in keeping that clothing clean.

You will learn, too, that we get most of our heat from the sun. But you will find it is possible to transfer heat from one place to another, from a furnace in the basement, for example, to a room upstairs.

You will learn also how man uses the heat energy of steam for driving a steam engine, or the heat energy from exploding gasoline vapor for driving the engine which runs his automobile or airplane.

Think about these!

1. Do you think that heat and temperature are the same?
2. What are some of the effects that heat produces?
3. Why do snow and ice melt so slowly in the spring?
4. How can an electric motor be used to make ice?

Words for this chapter

Mechanical. Pertaining to a machine.
Thermostat (thûr′mō·stăt). A device for automatically regulating the temperature.
Fusing. Liquefying or melting.
Sea level. The level of the surface of the sea.
Refrigerant (rē̇·frĭj′ẽr·ănt). A substance used in cooling, or refrigeration.

CHAPTER 4 —————— UNIT 3

What Can Heat Energy Do?

66. What are the sources of heat? (*a*) Although there are several sources of heat, nearly all the heat we receive comes from the *sun.* The heat energy from the sun causes the evaporation of water, it causes winds and storms, and it supplies the energy needed by plants to make starch. Our earth would soon *run down* and become a cold, lifeless planet if it were not for the heat from the sun.

b) *Friction* causes heat, too. The ancients thought at one time that heat was a weightless fluid, which they called *caloric* (kȧ·lŏr′ĭk). But when Sir Humphry Davy melted two pieces of ice merely by rubbing them together, scientists were forced to conclude that *heat is a form of energy.* Friction increases the rate of motion of the molecules, and thus causes an increase in temperature. There are many examples. A match head may be heated up to its kindling temperature by rubbing it on a rough surface. We rub our hands to warm them by friction. The brakes of an automobile sometimes get hot enough to burn when they are applied steadily for some time, in going down a long hill, for example.

We have reason to believe that the *interior of the earth* is highly heated. Molten rock issues from volcanoes and boiling water from geysers. The Calumet and Hecla copper mine in northern Michigan is over a mile in depth. The lower levels in this mine are so hot that it is difficult to cool them enough so that men can work even when compressed air is used for ventilation.

c) *Chemical action* is an important source of heat energy. We use the energy from burning wood, coal, or oil to keep our houses warm in winter. The oxygen we breathe unites with the food we eat. This produces heat energy which keeps the temperature of our bodies at about 98.6° F., summer or winter.

67. What effects does heat produce? In our study of heat, we are interested to learn what heat can do. In your study of the thermometer, you learned that heat causes mercury, alcohol, and many other substances to *expand,* or to grow larger. When they cool again, they *contract.*

If we put a pan of water on a hot stove, we find that the temperature of the water rises as we continue to add heat to it. One of the effects of heat, then, is *to increase the temperature of the substance to which the heat is applied.* If we subtract heat from a substance, we lower its temperature.

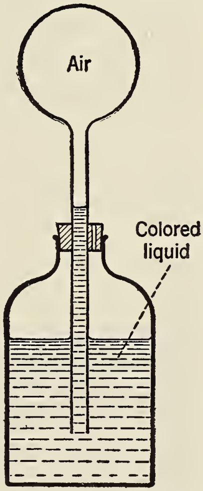
If we add heat to a piece of ice, it melts or changes from a solid state to a liquid state. If we continue to add heat to the water that forms as the ice melts, the liquid water will change to water vapor. Therefore, heat may be added to a solid *to change its state* to a liquid, or possibly to a gas. If we subtract the heat from a gas, it may change to a liquid, and if we continue to subtract more heat from the liquid, it will eventually freeze. Thus we see that *heat can change the state of matter.*

There is another important effect which heat can produce that we shall merely mention in this chapter, and study in more detail later. We have seen that *mechanical* energy can be changed into heat, as by friction. It is a poor rule

that does not work both ways, and we find that it is possible to use heat energy to operate machines, such as the steam engine or the gasoline engine.

68. How do we measure temperature? In your seventh-grade study, you learned how to make a thermometer. Galileo made the first thermometer by the use of a bulb to which a long hollow tube was attached. The tube and bulb were both full of air. Then Galileo let the open end of the tube stand in a colored liquid, as shown in Figure 4–1.

FIG. 4–1. If one holds his hand on the bulb of such a thermometer, the heat from his hand will cause the air inside to expand and push the colored liquid downward in the tube. How would a scale attached to such a thermometer differ from the scale attached to a mercury thermometer? How does a change in air pressure affect such a thermometer?



When the air in the bulb is heated, it expands and pushes some of the air out of the tube. As it cools again, the colored liquid rises in the tube. One can tell the temperature by reading a scale, alongside the tube, by which the rise and fall of the colored liquid in the tube are measured.

The instrument used to measure temperature is a thermometer of one kind or another. The principle used in making a thermometer is the expansion of some gas, some liquid, or even some solid, to indicate the temperature. Mercury and colored alcohol are most often used, although metal may be used in oven thermometers.

*69. How is a clinical thermometer constructed? The *clinical* (klĭn′ĭ·kăl) thermometer, or thermometer used by a doctor or a nurse in order to take a patient's temperature, differs from the usual thermometer in two ways:

a) It is very short, because it is seldom that anyone has for long a temperature lower than 92° F., or higher than 110° F. A fever that causes a temperature higher than 108° F. is likely to prove fatal, and few persons survive a chill which lowers the bodily temperature more than four degrees below normal and keeps it there for any length of time. The degree marks on the scale of the thermometer are farther apart than they are on the ordinary thermometer, and it is possible to read to tenths of a degree. [See Fig. 4–2.]

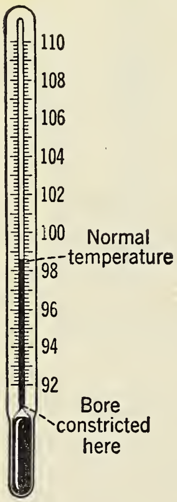


Fig. 4–2. No doubt you have seen such a thermometer many times. Possibly your mother has one which she uses to check your temperature when you have a cold or are seriously ill. You will observe that it has a shorter stem than the ordinary thermometer. Why must a person jerk such a thermometer a few times before he uses it?

b) The opening in the tube of this thermometer is reduced in size just above the bulb. The mercury can easily push its way past such a *constriction,* or narrowed portion, but it does not flow back again when the temperature falls. Because the mercury stands at the highest temperature that was reached, the doctor can read the temperature at his convenience. Then he gives the thermometer several quick

jerks to force the mercury back into the bulb so that the thermometer will be ready for the next reading.

70. How can we prove that solids expand when heated? If you are a careful observer, you will notice that telephone and telegraph wires sag much more in summer than they do in winter. Sometimes in very cold weather they contract so much that they break. Two thousand feet of copper wire will expand a little more than one foot if it is heated through about 60° Fahrenheit, as from 30° F. to 90° F., for example. The farmer who builds a wire fence in summer must make some provision so that the wires will not break in cold weather, because the force of contraction is tremendous. One manufacturing company makes a wire fence in which springy wires are somewhat crinkled or wavy. When the wires contract, they tend to straighten a little, but they do not break. When the temperature rises, the wires are elastic enough so that they return to their original wavy shape.

Concrete walks sometimes expand so much in summer that

FIG. 4–3. Summer heat caused this road in Illinois to buckle as you see. How can frost make a road buckle? (*Courtesy Public Roads Administration*)

they buckle, or warp. In making concrete roads, joints filled with tar are used to permit expansion without the buckling of the concrete. [See Fig. 4–3.]

Let us use a brass ball and ring to demonstrate the expansion of metals when heated and their contraction upon cooling. First we notice that the ball passes through the ring fairly easily. [See Fig. 4–4.] We then heat the ball rather

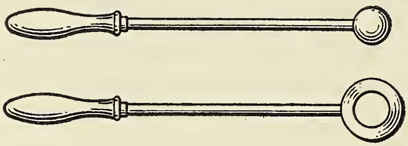


Fig. 4–4. The cold ball passes through the ring, but the heated ball cannot.

strongly. It will no longer pass through the ring. Next let us heat the ring. It then passes over the ball easily. If we then pour cold water over the ring, we cannot remove it over the ball because it has contracted too much. If we then pour cold water over the ball, we find that the ring can then be easily removed. *Almost any solid expands when it is heated, and contracts when it is cooled.* Some solids expand much more than others, when equal lengths are heated the same amount.

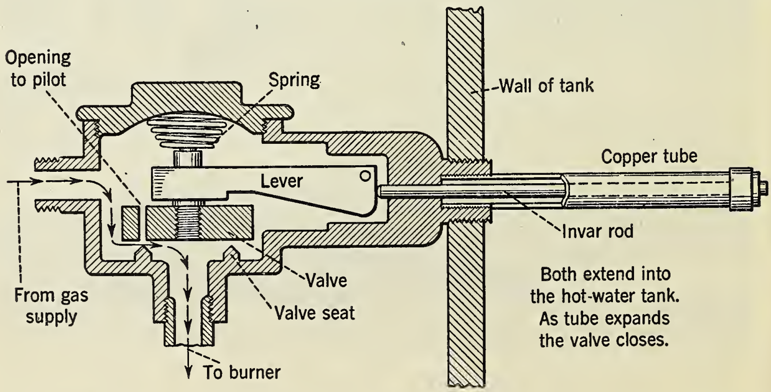
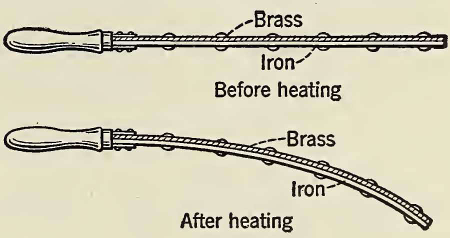


Fig. 4–5. As the water in the tank gets warm, the heated tube expands and shuts off the gas.

71. **Is there any practical use for expansion?** Rivets are heated red hot before they are used to rivet together two steel plates. When they cool, they contract and make a very tight joint. In some water heaters, a metal tube on the inside expands with the increasing heat, and turns off the gas when the water reaches a certain temperature. The rod inside the tube is called *invar* because it is made of material that does not vary much in length when heated or cooled. As the water cools, the tube contracts and permits the gas to flow again. It is then lighted by a small pilot light. Thus the water is automatically kept at a certain temperature. [See Fig. 4–5.]

72. **How does a compound bar behave when heated or cooled?** A compound bar consists of two strips of different kinds of metal, such as brass and iron, welded, soldered, or riveted together to make one solid piece. When it is heated, brass expands about one and a half times as much as does iron. [See Fig. 4–6.] When it is heated, the metal will bend

FIG. 4–6. Brass expands more than iron does when it is heated and it contracts more upon cooling. Can you make a sketch to show how this compound bar would appear if it were cooled decidedly?



as shown in the figure. If such a bar is cooled below normal, it will bend in the opposite direction.

73. **For what purposes is the compound bar used?** Possibly you have a thermometer on your gas oven. If so, it probably consists of a compound bar which coils up when heated and straightens out when cooled. As it does so, it moves a pointer over a scale from which the temperature can be read. [See Fig. 4–7.]

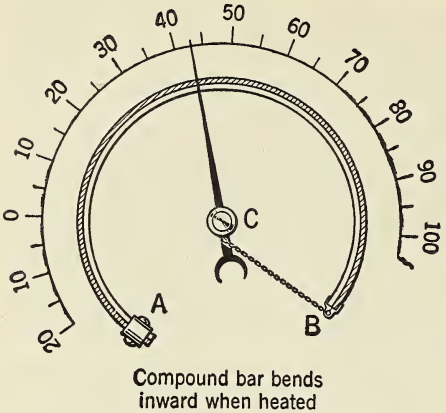
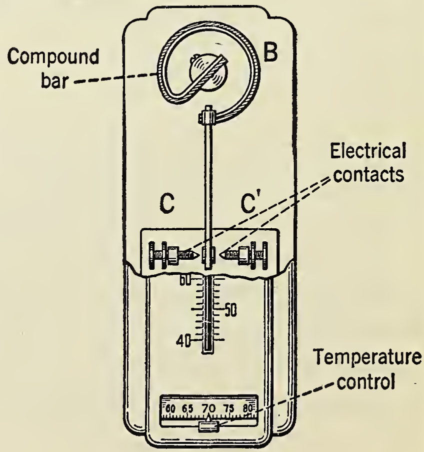


FIG. 4–7. Heating such a curved bar makes it coil up into a smaller circle. How does the pointer move? When the bar is cooled, it expands to form a larger curve. How does the pointer move?

A compound bar is often used in the operation of a *thermostat* which controls the temperature of rooms. [See Fig. 4–8.] The compound bar is curved. One end is fixed, and the other is fastened to a pointer that can move back and forth between two electrical contacts. As the temperature of the room rises, the brass strip in the compound bar expands and increases the curve of the bar, thus moving the pointer to the left, until it touches the electrical contact. This operates a motor which closes the drafts of the furnace. As the room cools, the brass contracts, lessening the curve of the bar and

FIG. 4–8. The curved bar here behaves exactly like the one shown in Fig. 4–7. As the room in which the thermostat is placed cools, the pointer touches the electrical contact C′. This contact operates a motor which causes the furnace door to open. The door is closed again when the pointer touches the contact point C.



moving the pointer to the right, until it touches the other electrical contact. This contact operates a motor which opens the drafts.

A compound bar may be used also in a thermostat which prevents the overheating of an electric iron by breaking the circuit when the danger temperature is reached. For several other purposes, also, the compound bar is useful.

74. How can we prove that liquids expand when heated? Suppose we have a flask which holds about 250 cubic centimeters. We fill it with water, and close it with a one-holed rubber stopper, in which there is a piece of glass tubing from 8 to 10 inches long. If we heat the flask, as shown in Figure 4–9, we find that the water in the flask expands and that some of it is pushed up into the glass tube.

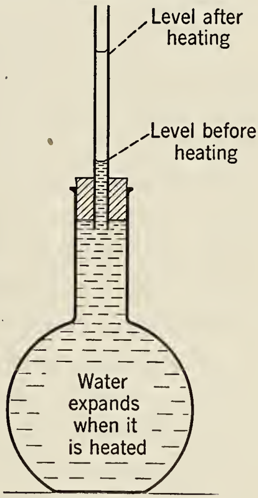


FIG. 4–9. A flask which is fitted with a rubber stopper and a glass tube of small diameter may be used to show that liquids expand when heated. Using such a flask, see whether the warmth of your hands is great enough to cause the liquid in the tube to rise.

Possibly your mother cans fruit, or bottles grape juice, in the canning season. If so, she fills the cans or the bottles entirely full of the hot liquid, and then seals them so that they are airtight. In a few hours the cans or bottles have cooled. Then you will find that they are no longer entirely full. These two observations show that *liquids expand when they are heated, and contract when they are cooled.*

Of course anyone who has ever used an ordinary thermometer knows that the liquid in the thermometer expands when heated and contracts when cooled. He learns, too, that the mercury expands more than the glass does, and that it contracts more when it cools. In all cases, liquids expand more when they are heated than solids do, and they contract more when they are cooled. Some liquids expand more for each degree they are heated than other liquids do.

A man had his gasoline tank filled late one evening. He then drove to his home, which was about one mile away. The next morning he drove a few blocks to church and parked his car while he attended church services. His car stood in the sun. When the man returned to it, he found that the gasoline in the tank had been overflowing. Can you explain what had happened?

*75. **Water is peculiar in its expansion.** If we take one quart of water whose temperature is exactly 0° Centigrade, and warm it to its boiling temperature, 100° C., we observe that it behaves in a peculiar way. At first it begins to *contract,* and it continues to contract slightly as it is warmed from 0° C. to 4° C. When it reaches that temperature, it stops contracting. Hence water at 4° C. is denser than it is at any other temperature. *One cubic centimeter of water at that temperature weighs exactly one gram.*

As we warm the water above 4° C., it expands until its boiling point is reached. If we cool water from the boiling temperature, it contracts, continuing to do so until it reaches a temperature of 4° C. Then it expands again until it reaches the freezing point. You have already learned that

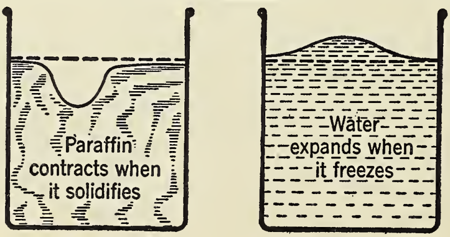


FIG. 4–10. We learned that water expands when it changes into ice. You notice how it bulges up in the cup as it freezes. Paraffin contracts when it changes from a liquid to a solid.

water expands decidedly when it freezes. [See Fig. 4–10.]

76. Do gases expand when they are heated? Baking powder is added to the flour used for making biscuits or cake. When the water or the milk is added, the baking powder begins to give off the gas *carbon dioxide.* This gas becomes entangled in the biscuit dough and is distributed through it when the dough is put into a hot oven. The biscuit dough rises because the gas, entrapped inside, expands when it is heated.

Suppose we inflate a football in a very warm room. If we let it remain outdoors where the temperature is low, the air inside will contract, and the football will become much softer than it was before.

We may inflate an automobile tire to 30 pounds per square inch on a cool morning. If that tire is permitted to stand in the sun, the air inside attempts to expand. It cannot expand very far, but the expansion will increase the pressure inside the tire by a few pounds per square inch. Do you think that a blowout is more likely to occur when a tire stands in the shade or in the hot sun? Tires also become hot from internal friction after a few hours of driving. It may prevent a blowout if such tires are deflated to some extent.

77. How is heat measured? To measure temperature, we use a thermometer. The temperature is measured in degrees. But heat differs from temperature, and we must have a different unit for measuring it. For example, a burning match has a rather high temperature, but it does not warm a great deal the room in which it is burned. A steam radiator has a much lower temperature than the burning match, but it furnishes a much greater total heat energy for use in heating a room.

A tubful of warm water may have in it more heat energy than a cupful of boiling water, but a thermometer shows that the water in the cup has a higher temperature. We have already learned that the unit used for measuring heat is called the *calorie* (kăl′ŏ·rĭ).

The calorie is really a measure of what heat can do. For example, *one small calorie of heat can warm one gram of water one degree Centigrade.* There are 454 grams in one pound. To warm 20 grams of water one degree, we need 20 calories of heat. It is true, too, that it must take 20 calories to warm one gram of water twenty degrees Centigrade. To warm 20 grams of water 20° C., of course one would need 400 calories. As one gram of water cools through one degree Centigrade, it loses one calorie of heat.

The amount of heat needed to warm one pound of water one degree Fahrenheit is called the *British Thermal Unit.* In diet tables, the calorie that is used to measure heat is just one thousand times as large as the calorie defined in the preceding paragraph. This unit is called the *large calorie,* or the *kilocalorie.*

78. **How may heat affect a solid?** If we warm a solid, its temperature rises. After a time, its temperature stops rising, and it may begin to melt. It continues to absorb heat, however, as it melts, or changes to the liquid state.

Nearly all solids have a definite temperature at which they begin to melt. That temperature is called the *melting point.* For example, ice melts at 32° F., or at 0° C. Lead does not melt until it is heated to a temperature of 327° C., and iron must be heated to a temperature of 1550° C. before it will melt. In making castings, melted iron is poured into sand molds or cavities and then permitted to solidify. The tungsten wires that are used to make the filaments for electric-light bulbs do not melt until the temperature reaches about 3000° C. Melting is also known as *fusing,* or *liquefying. Fuse* wires in an electric circuit melt when the current they are carrying becomes great enough to warm the wires to their melting point.

79. **What happens when we subtract heat from a liquid?** We set a pan of water out-of-doors on a cold winter night. The cold air keeps carrying heat away from the water. In time, the water is cooled until it reaches its *freez-*

ing point, or that temperature at which it begins to freeze. The changing of a liquid into a solid is called the *freezing, solidifying,* or *congealing* of the liquid. It happens that all substances which form crystals when they solidify will both melt and freeze at exactly the same temperature.

80. How does the volume of a liquid change when it freezes? You will recall that milk expands when it freezes, and that it may push the cap up out of the bottle in which it is contained. The bottle may be broken, too. Milk is about 87 per cent water, and it is the water in the milk which expands when it freezes. When water freezes, it increases in volume by about 10 per cent. In other words, the ice formed takes up about 1.1 as much space as did the water from which the ice was formed. Of course ice is only about 0.9 as dense as water.

All liquids which form crystals when they freeze expand in a similar manner when they solidify. A substance which does not form crystals when it freezes, contracts and takes up less room as it changes from a liquid state to a solid state.

81. Why does ice melt slowly? Possibly you have wondered why the snow and ice linger so long in the spring. The sun is warm and the temperature of the air is much above the melting point of snow or ice, and yet the snow man that someone built and the drifts in corners are slow in disappearing. What is the answer?

Let us perform a simple experiment. We shall put on the stove a pan of water containing several lumps of ice about as large as walnuts. As we heat the water, we shall keep stirring the ice and water with a thermometer. We find two rather strange things. (*a*) It takes several minutes to melt all the ice. (*b*) If we heat the pan slightly, the temperature of the water in the pan will not rise above 0° Centigrade until all the ice has melted. We must conclude that all the extra heat which was being absorbed *must have been used to melt the ice.*

Scientists are able to show by experiment that *it takes 80*

calories of heat just to melt one gram of ice. During the melting, a thermometer does not show any change in the temperature of the melted ice. If it takes 80 calories just to change one gram of ice at 0° C. into water at 0° C., then it is not difficult to understand why snow and ice melt slowly. [See Fig. 4–11.]

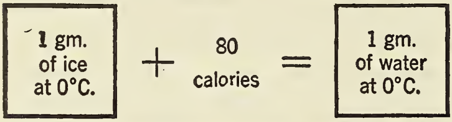
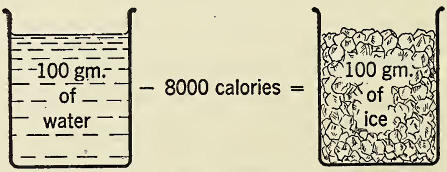


Fig. 4–11. Can you explain how this diagrammatic equation illustrates the heat of fusion?

***82. Must water lose heat before it can freeze?** Just as you may have wondered why snow and ice melt slowly in the spring, you may have wondered why you need to wait so long in early winter before the ice becomes thick enough to be safe for skating. If you think carefully, you may be able to answer your own question.

No energy is ever lost. Since it takes 80 calories of heat just to melt one gram of ice, then it seems probable *that every gram of water at 0° C. must lose 80 calories before it can change to ice at 0° C.* Now you can understand why it may take several cold nights before the air can subtract enough heat from the water in a lake, pond, or river to make the water freeze. [See Fig. 4–12.]

Fig. 4–12. From one gram of water at 0° C., one must subtract 80 calories to change the water into ice.



83. Why do liquids evaporate? In your earlier study of science, you learned that increasing the temperature of a substance makes its molecules move more rapidly. *Molecules* are the smallest particles in which matter can exist without losing its properties. If you could see the molecules in a substance whose temperature was being increased, they might appear as shown in Figure 4–13. The rapidly mov-

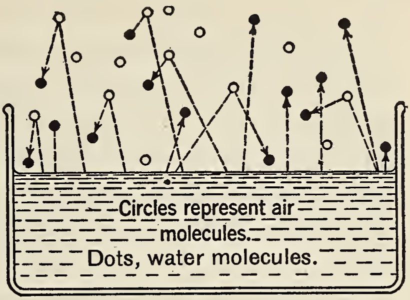


Fig. 4–13. The water molecules are in constant motion. Those at the surface escape into the air. They are retarded by the molecules that are present in the air. As more water molecules enter the air, they help to retard evaporation.

ing molecules escape from the surface of the liquid and pass off into the air. Such a process of changing a liquid into a gas or a vapor is called *evaporation* or *vaporization.*

84. How is it possible to increase the speed of evaporation? Any factor that can cause the moving molecules of water, for example, to escape more rapidly from the surface of the liquid will speed up the evaporation. Let us mention a few such factors.

a) *By increasing the temperature.* If we heat water, we cause it to evaporate more rapidly. This must be true, because the speed of the moving molecules increases as the temperature rises.

b) *By increasing the amount of surface.* If we wish the laundry to dry quickly, we spread it out upon a line instead of keeping it rolled up in a clothes basket. Spreading it out increases the surface from which the molecules can escape. It seems to be good common sense to believe that one quart of water will evaporate more quickly from a broad, open pan than from a quart milk bottle.

c) *By keeping the air in motion.* Every laundress knows that clothes dry quickly on a windy day. The air near the garments may become nearly saturated with water vapor. The wind carries away the saturated air and brings in other air which can take up moisture. In a similar manner, an electric fan pushes fresh air toward us and causes the perspiration on our skin to evaporate faster on hot days. Such fanning tends to cool us even though the temperature of

the artificial breeze is no lower than that of the still air.

d) *By removing the air from above the surface.* If a boy wishes to break a record in a hundred-yard dash, he does not go to a busy corner in New York, Chicago, or some other city. If he did, he would bump into one person after another, often be knocked backward, and have his speed reduced. In a similar manner, the molecules trying to escape from the surface of a liquid strike some molecules in the air and rebound into the liquid again. [See Fig. 4–14.] If we remove

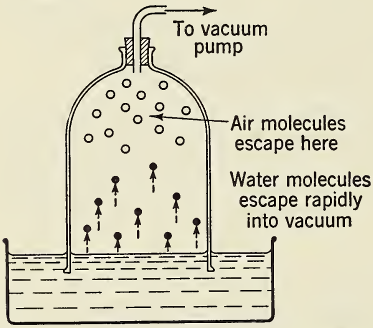
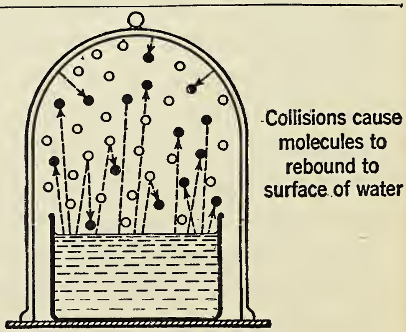


FIG. 4–14. One cannot make speed on a crowded street. If we remove the molecules above a liquid surface by using a vacuum air pump, evaporation is hastened.

the air molecules by pumping away the air above the liquid, the molecules of moving liquid will then have a free field. This explains why liquids evaporate rapidly in a vacuum.

e) *By lower relative humidity.* If air is saturated with water vapor, we may imagine a picture similar to that shown in Figure 4–15. A number of water molecules may be escaping from the liquid surface each second. Some of those

FIG. 4–15. It is possible to have the air above a liquid saturated with vapor. The bell glass prevents the saturated water vapor from escaping and mixing with air that is not saturated.



escaping molecules will collide with molecules in the air and rebound to the water surface again. Others will collide with water molecules already in the air and rebound too. Suppose that one million molecules escape from the liquid each second and that one million rebound per second and return to the liquid again. That is the picture of saturated air when the relative humidity is 100 per cent. Since the number of escaping molecules is equal to the number of molecules returning to the water, there seems to be no evaporation at all when the air is saturated. Loss of water by evaporation becomes slow when the relative humidity rises to 80 per cent or 90 per cent. *When the relative humidity is low, then water evaporates more rapidly.*

85. What happens when we heat a liquid? As we keep on heating a liquid, its temperature continues to rise until its *boiling point* is reached. The whole mass of the liquid is then thrown into violent motion. The temperature at which such disturbance occurs is called the boiling point of the liquid. Every pure liquid has a definite boiling point.

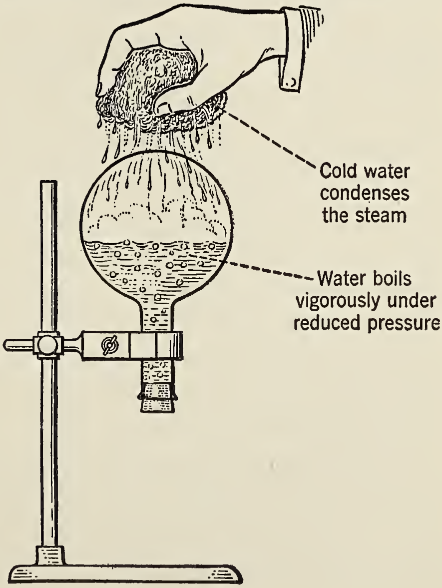


FIG. 4–16. There is boiling water and steam in the flask. By condensing the steam in the flask with the aid of cold water poured over it a partial vacuum is produced. Then the water boils rapidly. It will continue to boil until enough water vapor accumulates in the flask to produce enough pressure to stop the boiling of the water.

For example, ether boils at 35° C., and water at 100° C. To be strictly correct, however, we must say that water boils at 100° C. *at sea level.* At sea level, the air pressure is said to be that of *one atmosphere,* or 14.7 pounds per square inch. At a pressure which is less than that of one atmosphere, water boils at a temperature lower than 100° C. At the top of a rather high mountain, the boiling point of water may be 90° C., or even less. [See Fig. 4–16.]

86. Why does water "boil away" so slowly? Suppose we put a quart of ice water in a pan over a gas burner, and observe the time needed to warm that water *to the boiling point.* Let us observe, too, the time needed, after the boiling point is reached, for all the water to "boil away." We find that it really takes *more than five times as long to "boil away"* one quart of water as it did to warm the water from its freezing point to its boiling point.

The steam that is formed by boiling water has exactly the same temperature as the boiling water has, but it actually contains more heat units. Carefully performed experiments show that *it takes 540 calories of heat merely to change one gram of water at 100° C. into steam at 100° C.* We say that 540 calories may be called *the heat of vaporization of water,* because that is the number of calories needed to evaporate one gram of water after we have heated it to its boiling point.

If we hold a thermometer in boiling water, we can easily show that the water is no hotter when it is boiling vigorously than it is when it is boiling slowly. How can you save gas when you boil potatoes? Turn the gas on just full enough so that much of the flame will be beneath the pan while the water is warming to the boiling point. Then when the water begins to boil, turn off the gas until it is just hot enough to keep the water boiling slowly.

87. Why does the evaporation of water produce a cooling effect? It takes more than 540 calories of heat to evaporate one gram of perspiration from our skin. Where does the heat come from? Most of it is taken from our bodies.

Subtracting heat from the body will naturally make it cooler. We feel cool in summer when we sit in a breeze because the wind makes the perspiration evaporate faster.

For the same reason, sprinkling the streets in summer produces a cooling effect. The heat needed to evaporate the water is subtracted from the streets and the air surrounding them. Thus they are cooled.

88. What happens to the heat when water vapor condenses? Here, too, we need to remember that energy is never lost. We learn that it is necessary to *add much heat to water to convert that water into vapor.* [See Fig. 4–17.] When the vapor condenses again to form water, all the added heat is set free. In fact, every gram of steam that condenses to form boiling water loses 540 calories of heat. It may then continue to lose heat as it cools down to room temperature.

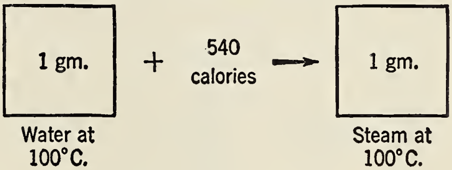


FIG. 4–17. Adding 540 calories of heat to one gram of water at 100° C. changes the water into steam.

This explains why steam produces a more severe burn than does boiling water of the same temperature. As it condenses, the steam loses the 540 calories of heat that were needed to change each gram of water to steam, and much of that heat is released to that part of the skin in contact with it.

89. How do we distill a liquid? Let us put a water solution of salt into the distilling flask as shown in Figure 1–19, on page 25. When the water is boiled, the steam passes through the outlet tube of the flask and through the inner tube of the condenser. Cold water flows around this inner tube and condenses the vapor to form water. First we have *evaporation.* Then we have *condensation of the vapor.* Such a double process in which both evaporation and condensation

occur is called *distillation.* The salt which was dissolved in the water does not evaporate, but it remains in the flask. Solids dissolved in water may be recovered again by boiling away the water. The water which distills over is free from impurities. Hence, distillation is used to purify water. Although distilled water is pure, it is flat and tasteless. If it is aerated, however, its flavor may be improved.

90. What is fractional distillation? It is not at all uncommon to have a mixture of two liquids. It is possible to separate them by distillation, provided they have different boiling points. For example, alcohol boils at 78° C., and water boils at 100° C. When a mixture of alcohol and water is distilled, most of the alcohol boils off before the boiling point of the water is reached. Of course some water evaporates and passes off with the alcohol, but the distilled portion contains a higher per cent of alcohol than the original mixture had contained. Thus liquids which have different boil-

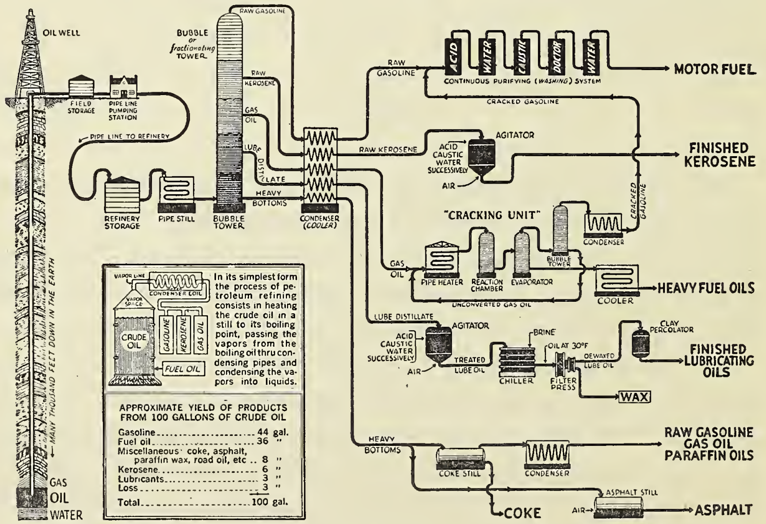


FIG. 4–18. At the left is an oil well. The different liquids are separated and run off into separate containers. (*Courtesy Socony-Vacuum Co.*)

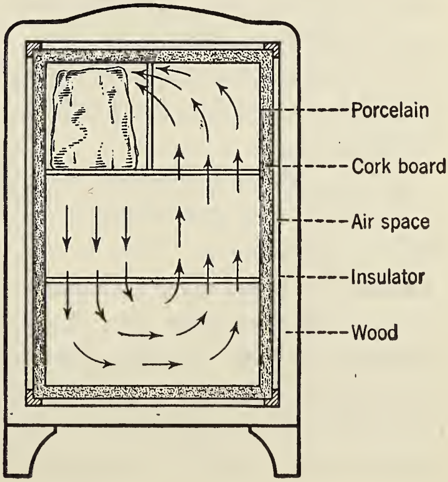
ing points may be separated by *fractional distillation.*

Petroleum is a mixture of liquids which have different boiling points. When petroleum is distilled, the liquid having the lowest boiling point distills off first. It is followed by the other liquids in the order of their boiling points. For example, one fraction is naphtha; another is gasoline; and a third is kerosene. There are many others. [See Fig. 4–18.]

91. Upon what principle does refrigeration depend? Suppose we place in contact with each other two or more objects which have different temperatures. The warmer ones lose heat and the colder ones gain heat until all have the same temperature. *Heat exchange* is taking place all the time in such a manner. We are accustomed to think of the heat as flowing from the warmer object to the colder one. We depend upon the principle of heat exchange in refrigeration. We shall discuss briefly two methods:

a) *The use of ice.* The food to be preserved by being kept cool is placed in a box with two or three compartments. The partitions have plenty of holes in them so that the air can circulate freely from one compartment to another. The ice is usually placed in the top compartment. [See Fig. 4–19.]

FIG. 4–19. A good refrigerator must have well-insulated walls to keep the heat outside the refrigerator from getting inside. As the ice inside melts, it takes heat from the air and the foods inside the refrigerator. Do you know how the air in a refrigerator circulates through all of the compartments?



When the food is first placed in the refrigerator, it is warmer than the ice. The heat absorbed from the food melts a part or all of the ice. We use the ice in the refrigerator because, in melting, each gram of the ice requires so many calories. (It takes 80 calories per gram, and there are 454 grams in one pound). As we take heat from the food, of course we lower its temperature.

*b) *The use of mechanical refrigeration.* All types of mechanical refrigerators depend upon the cooling effects of evaporation for their operation. [See Fig. 4–20.] Suppose you try the following experiment: Pour a little water over the back of your hand and then wave your hand around to make the water evaporate quickly. Repeat the experiment, wetting the hand with alcohol for the second trial. In both cases the hand will feel cooler, but it will feel colder after being wet with alcohol than it did after being wet with water, because alcohol evaporates faster than water does. It takes heat from the hand faster than water does. Suppose you try a third time, wetting the hand with ether. The ether evaporates so fast that it feels very cold to the hand. Ether boils at about 35° C. Now what do you think would be the effect if you poured upon your hand some liquid ammonia, which boils at 34° C. below zero? If you kept up such an experiment for a short time, your hand would soon be frostbitten because the extremely rapid evaporation of the liquid ammonia would take heat from your hand so rapidly that it would freeze.

In the coils of an electric refrigerator, as shown in Figure 4–20, there is a gas which is easily liquefied by cooling it and compressing it. This is called the *refrigerant*. *Sulfur dioxide* has been used, although some less-known gases are now in more common use. A small electric motor is used to compress the gas. But compressing a gas causes its temperature to rise. In order to take away the heat produced by such compression, the gas flows through a series of coiled pipes around which cold air circulates. Because the cold air re-

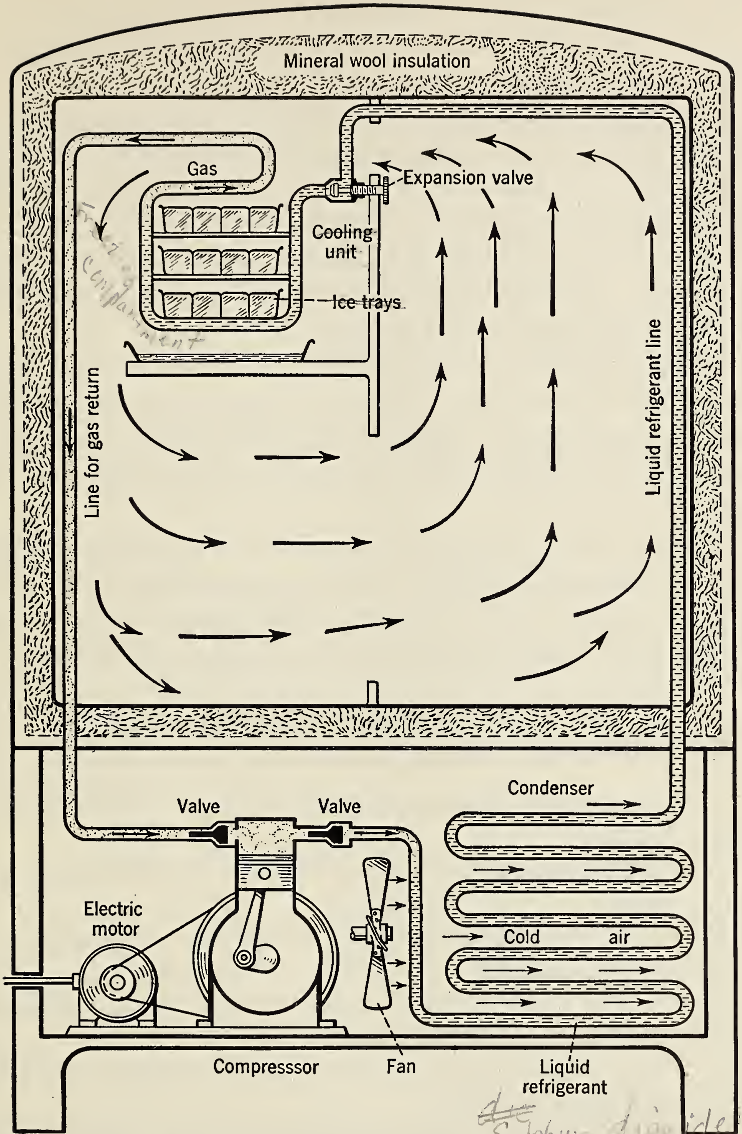


Fig. 4–20. The gas from the compressor is cooled in the condenser and changed into a liquid. In the cooling unit this liquid evaporates and takes enough heat from the water in the ice trays to change the water into ice. What do you know about the care of an electric refrigerator such as this one?

moves much of the heat from the compressed gas, the gas changes to a liquid.

The liquid is then pumped up into the refrigerator where it is permitted to flow through a tiny opening into a second set of coils. In those coils it evaporates and expands greatly. Both processes require heat. The heat is taken from the pans of water which are placed inside the coiled pipes, or *freezing coils.* As soon as the water in the pans loses enough heat, it freezes and forms artificial ice.

The gas formed when the liquid in the freezing coils evaporates then goes back to the compressor to be compressed and liquefied again. Thus the refrigerant keeps circulating continuously through the compressor and the two sets of coils.

The air in the refrigerator is cooled as it circulates around the freezing coils and the various compartments. Heat is taken from the foods in just the same manner as in the ice refrigerator. Subtracting heat from foods cools them.

Questions

1. What are some of the proofs that the interior of the earth is highly heated?
2. What are some of the important effects which heat produces upon matter?
3. In what ways does the clinical thermometer differ from an ordinary thermometer?
4. Why is a winter in which there is much freezing and thawing destructive to roads and streets?
5. Why is it necessary in winter to use an antifreeze solution in an automobile radiator?
6. Why does pouring hot water over the top of a fruit jar sometimes help in loosening the cap?
7. Which do you think weighs more, one cubic foot of ice water or one cubic foot of boiling water?
8. Which do you think weighs more, one cubic foot of water at 4° C., or one cubic foot of water at any other temperature?

9. How many calories of heat will 50 grams of water lose in cooling from 70° C. down to 20° C.?

10. Do all liquids have the same boiling point?

11. Why are water pipes likely to burst when they freeze?

12. Why do snow and ice melt slowly, even during a warm day in spring?

13. When cold weather comes, you usually must wait several days before you can go skating. Explain why.

14. How can you hasten the evaporation of water?

15. Why does fanning the face make one feel cooler?

16. Why does steam produce a more severe burn than boiling water does?

17. For what purposes is distillation used?

18. What are the purposes of fractional distillation?

19. What heat exchanges occur in a refrigerator?

20. Upon what scientific principle does mechanical refrigeration depend?

21. Explain how it is possible for a heavy rainstorm or a heavy snowstorm to warm the air.

22. The story is told of a man who would never buy gasoline from one of those old-fashioned glass cylinders that stood in the sun. If you warm 20 gallons of gasoline through about 35 Fahrenheit degrees, it will expand about one quart and a half. Was the man scientific?

Some things for you to do

1. A cubic foot of ice weighs about 57 pounds. If you have an ice refrigerator, find the capacity of the ice chamber in cubic feet. Then calculate the number of pounds of ice it can hold. How can you use your fingers or a foot rule to check on your iceman?

2. Fill a pan about half full of water and add several lumps of ice as large as walnuts. What temperature changes do you observe as you stir the mixture with a thermometer?

3. Hold a thermometer in a pan of slowly boiling water. Repeat when the water is boiling rapidly. What change, if any, do you observe in the temperature? (You must use a thermometer which registers at least 100° C.)

THINK ABOUT THESE!

1. How does the heat get from your furnace to your room?
2. Which seem colder in a cold room, cotton sheets or woolen blankets?
3. How does a thermos bottle keep its contents hot or cold?

WORDS FOR THIS CHAPTER

Conduction. That method of transferring heat in which the heat passes from molecule to molecule.

Convection. That method of transferring heat by the intermingling of the heated masses.

Radiation. That method of transferring heat by the transmission of waves; from the sun, for example.

Lampblack. A fine soot deposited from the smoke of oil, tar, and other substances.

CHAPTER 5 _______________ UNIT 3

How Does Heat Energy Move from Place to Place?

92. How does heat get from place to place? In summer, many of us enjoy pictures of snow. In midwinter, the glistening sand of a bathing beach or the crackle of a roaring fireplace is more appealing. We get all our heat from the sun, directly or indirectly. But it does not always come just when we want it and it is not always distributed to suit us.

In this chapter, however, we shall learn how the heat from our furnaces can be distributed through the various rooms of the house. If we learn, too, how heat travels from one body to another or from place to place, we may be able to speed it on its way when such a plan meets our needs, or to have it linger, by keeping it from escaping from the place where it is wanted. In large ways we are still helpless, but in small ways, man is learning how to *condition* the air — to make it pure and sufficiently damp. It has been learned that there are three ways in which heat energy is transferred from

one place to another, or from one object to another. They are called *conduction*, *convection*, and *radiation*.

93. What is conduction? Suppose you hold one end of a stove poker in a bed of live coals. After some minutes, you find that the other end of the poker becomes too hot to hold comfortably. The heat is being *conducted*, or *led*, along the poker from one end to the other. Probably the heat energy in the live coals makes the molecules of that portion of the poker which was in the fire vibrate faster and faster. The energy from the fast-moving molecules is then transferred to their neighboring molecules. In time, the whole poker becomes hot. Such transfer of heat from molecule to molecule we call *conduction*.

94. What are some good conductors of heat? Someone had to experiment in order to find the answer to this question. Let us take pieces of copper, brass, and iron wire, all having the same diameter and the same length. We may then twist the wires together at one end, making the twisted portion about three inches long, and leaving about six inches of the other ends of the wires separated as shown in Figure 5–1. We then proceed to heat strongly the twisted ends. If we hold a match head on each wire in turn, beginning at the far end, and sliding it toward the hot, twisted portion until it takes fire, we can find which of the three metals is the best conductor. It will be found to be that wire upon which

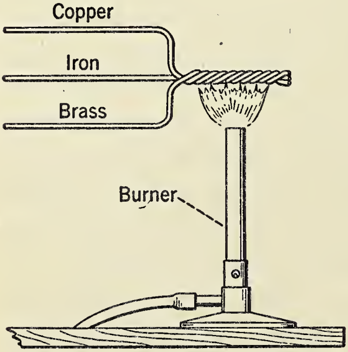
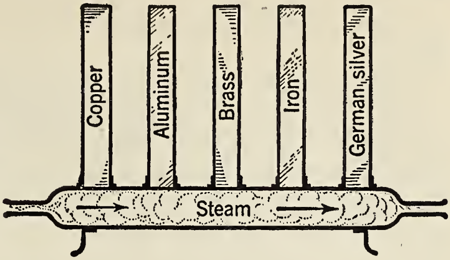


FIG. 5–1. Some metals conduct heat much faster than others do. Of the three pictured here, copper is the best conductor. If a silver wire were included in the diagram, where would it appear in relation to the others? Is aluminum a better or poorer conductor than copper? How does conductivity of heat influence the uses to which metals are put?

FIG. 5–2. As steam passes through the base of this apparatus, it heats the metal rods. Can you find out which rods will warm up soonest?



the match head will kindle at the greatest distance from the heat source. A different apparatus is shown in Figure 5–2.

By some such methods as those given in the preceding paragraph, it has been found that *all metals are good conductors of heat.* Silver is the best conductor known, followed in order by copper and aluminum. In fact, we find it the usual rule that *compact* solids are good conductors of heat. It is true, however, that silver conducts heat nearly 500 times as fast as concrete, more than 1000 times as fast as white sand, and about 10,000 times as fast as wool.

95. What are some poor conductors? Wood is only a moderately good conductor of heat, and sawdust is even poorer. Wool is a poorer conductor of heat than is cotton or linen, and silk is poorer than wool. All liquids are poor conductors of heat. Water, for example, is only about one

FIG. 5–3. Water resembles other liquids in that it does not conduct heat well. The water at the top may be boiled for some time before the ice at the bottom melts. Of what use to you can this information be?

eight-hundredth as good a conductor as silver. [See Fig. 5–3.]

Air, also, is a very poor conductor of heat. Silver, for example, conducts heat about 20,000 times as well as does air. All gases are poor conductors. It is interesting, too, to learn that gases become poorer and poorer conductors as they become less and less dense. A vacuum is a *nonconductor of heat*. Materials that are used as *insulators* are very poor conductors.

96. How do we use heat conductors? When we place an aluminum or iron skillet upon a hot stove and put some potatoes or a piece of meat into the skillet, we depend upon the metal to conduct the heat to the food in the skillet so that it can be cooked.

Some air-cooled motorcycle or airplane engines have metal plates or fins around the outside of the cylinder walls to conduct the heat rapidly away from the inside.

We use copper or brass for the heating coils in our hot-water heaters. The heat from a flatiron is conducted by the iron to the clothing that is being ironed. The heat from the inside of our radiators is conducted by the metal of the radiators to the outside surface, from which it is distributed to the rooms.

97. How do good conductors affect our feelings? When you were much younger, did you ever see a piece of metal covered with frost and start to lick the frost from the piece of metal? No doubt you were a little alarmed when you found that your tongue had frozen to the metal. When you jerked your tongue away, it probably tore off a small piece of skin from your tongue. Why did it happen? The metal was such a good conductor that it took heat from your tongue so rapidly that the saliva on your tongue froze immediately.

A rug lying on a tiled floor of a bathroom has the same temperature as the tile. If you are barefooted and step on the tile, it will *feel much colder* than the rug does when you

step on it. The tile is a better conductor of heat than the rug is, and it will take heat from your foot faster than the rug does. Therefore it feels colder.

Suppose a sleeping room is rather cold, having a temperature of about 50° F. There are two beds in that room, one fitted with cotton sheets, and the other supplied with woolen blankets. Suppose you try both beds, creeping in between the sheets of one, and then between the blankets of the other. Why do you find that the cotton sheets feel colder? They take heat from the body more rapidly because they are better conductors of heat than are the woolen blankets. The blankets, being better insulators, prevent the heat of the body from escaping.

Your mother is removing a pan of hot bread from the oven. Does she get a more severe burn if she touches the metal pan or if she touches the bread? Both have the same temperature, but the metal *feels much hotter* than the bread does, because it conducts more heat to the hand as it cools than the bread does. For that reason, the metal pan causes a more severe burn.

98. Does clothing ever supply you with heat? Does clothing of any kind ever give heat energy? It never does. Then how does it keep the body warm in winter? The body supplies its own heat energy, and *our clothing merely acts as a heat insulator and keeps much of the heat of the body from escaping.* The clothing which is the poorest conductor will keep us the warmest. A woolen sweater is warm in winter, because there are so many "dead" air spaces between the fibers of the garment. The air spaces are insulators, and they tend to keep the heat of the body from escaping. For the same reason, furs and feathers are very warm protection.

We find it hard to keep warm on a cold, *windy* day. The wind disturbs the "dead" air spaces and it blows through the garments and carries away the heat of the body. Can you understand why a newspaper wrapped around your

body, underneath your coat or sweater, helps to keep you warm?

99. Can we keep out heat? You have probably heard the remark: "What will keep out cold will keep out heat." It is better if we revise the statement to read as follows: "What will keep heat in will also keep heat out." In the preceding section we learned that our clothing keeps the heat of the body from escaping. If we are working around a furnace, for example, where the temperature may be warmer than the temperature of our bodies, then we need to wear woolen clothing to *keep out the heat.* We need the insulating effects of clothing on a hot sunshiny day to keep our bodies from being sunburned. We try to control the flow of heat by the proper choice of an insulator.

100. How do we use insulators? The use of clothing as an insulator we have already discussed. Let us mention a few examples of other insulators.

a) *The walls of houses.* Our houses are built of hollow walls. Hollow tile may be used to furnish insulating air spaces. In a frame house, we pack rock wool or some other insulating material between the lath (lȧth) and the sheathing. For the same reason, insulating material may be packed between the rafters, just beneath the roof. Double windows, with an air space between them, help to prevent the heat of the rooms from escaping in winter.

b) *Cellars.* We do not need much heat in the cellars of our homes. For that reason we put a layer of insulating material around the furnace and also around the steampipes. That layer or blanket is made of a mixture of magnesia and asbestos. It is very porous and full of air spaces. Therefore it keeps the heat of the furnace or the furnace pipes from

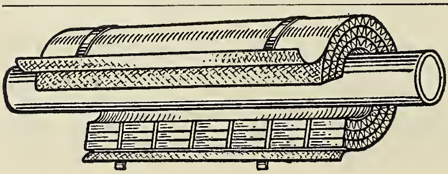


FIG. 5–4. Steampipes in the basement are usually covered with insulating material to prevent the escape of too much heat.

escaping into the cellar. It also helps to keep the heat from escaping from the steampipes to the walls of the houses as the pipes pass upward to the radiators. [See Fig. 5–4.]

c) *Refrigerators.* The walls of refrigerators are made double, or triple, and the spaces between the walls are packed with insulating material. Air cells or compartments may be used too. Then heat from the outside does not get in to melt the ice too rapidly. As a result, the ice takes heat mainly from the air and the food inside, and it is not wasted in cooling the air outside the refrigerator. The effectiveness of a refrigerator depends upon the thoroughness with which its walls are insulated.

d) *Fireless gas ranges.* Many modern gas ranges now have insulated ovens. A roast, for example, is put into such an oven and heated for about forty minutes. Then the gas is turned off. The heat in the roast itself, in the roaster, and in the heavy oven walls, is sufficient to finish cooking the roast, if the oven walls are well-insulated. [See Fig. 5–5.]

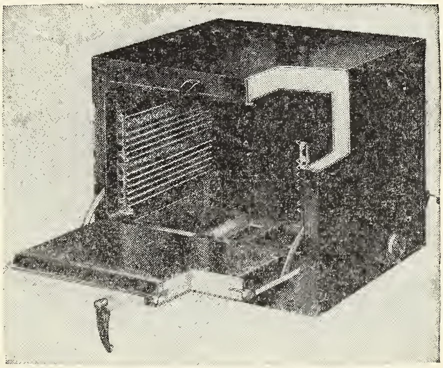


Fig. 5–5. This gas oven has thickly insulated walls. They have been cut into in this picture, so that you may see their thickness. Good insulation reduces the amount of heat required in using such an oven. For this reason, insulating saves you money. (*Courtesy Chambers Corp.*)

For cooking vegetables economically, one of the gas burners is set in a kind of insulated well. While the gas is on, the walls of the well are absorbing heat and storing it up in great enough quantity to finish the cooking after the gas has been turned off, perhaps ten minutes later. [See Fig. 5–6.]

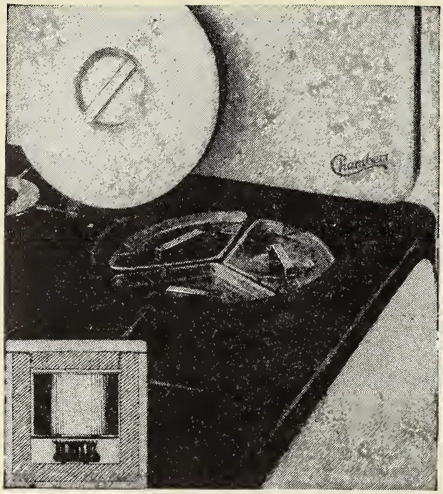


Fig. 5–6. Another modern invention which conserves fuel is the well-shaped and well-made burner. The proper shape sends the heat only to the places where it will be used. The well in this gas range is surrounded with material which can absorb much heat. It gets hot, and the heat stored is sufficient to complete cooking after the gas has been turned off. (*Courtesy Chambers Corp.*)

e) *Vacuum bottles.* A thermos bottle is blown with double walls, and the air is then pumped out of the space between the walls. If hot coffee is placed inside such a bottle, as in Figure 5–7, the heat from the coffee does not escape through the vacuum to the outside. If cold milk or some other liquid is placed in such a bottle, it will stay cold, because heat from the outside cannot get in through the vacuum, which is a nonconductor. Of course, coffee will not stay hot for indefinite periods of time. Some heat (since the temperature of the coffee is higher than that outside) will

Fig. 5–7. This diagram shows how the average thermos bottle is made. A hot liquid inside stays hot for 12 hours or more. What effect would the outside temperature have on this time? Do you think ice cream placed in a thermos bottle would melt quickly?

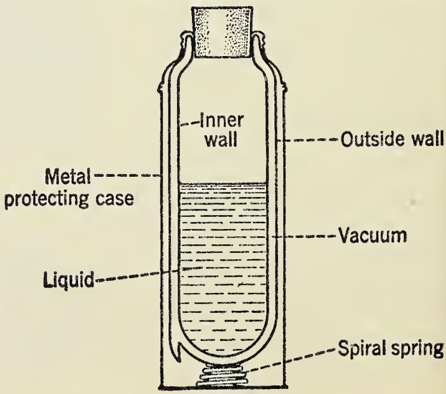


FIG. 5–8. A huge milk truck is being loaded for shipment. Why must the milk be kept cold while it is on the road? Are there any laws in your locality about such care? What care is taken of milk on a home-delivery route? (*Courtesy the Borden Co.*)

flow along the inside walls and escape through and around the stopper. In the same way, milk in a thermos bottle will not stay cold indefinitely, because heat (from the air surrounding the bottle) will travel inward along the glass walls and through the stopper.

Huge vacuum bottles mounted on trucks or on freight cars are used to transport milk. The milk is first chilled by letting it flow around pipes through which cold *brine*, or strong salt water, is circulating. Then the milk is poured into the vacuum bottles, in which it will stay cold for hours. [See Fig. 5–8.]

101. What is convection? When we study the weather and the causes of winds, we are really studying *convection* currents. The whole principle of distributing heat by con-

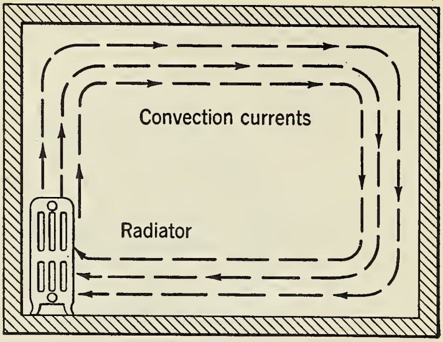


FIG. 5–9. The air above the radiator is heated. It expands and becomes less dense. Colder air from along the floor pushes the warmed air upward. Then the warm air is carried to the ceiling and other parts of the room.

vection depends upon the fact that cold liquids are denser than warm liquids, and cold gases are denser than warm gases.

Suppose we have a radiator in a room as shown in Figure 5–9. Steam from the furnace is pushed up into that radiator. The sections of the radiator are warmed from the steam by conduction. The air immediately above the radiator becomes warmer, too. It expands and becomes less dense than the air in other parts of the room, at the floor, for example. Currents of air drift along the floor toward the radiator and push the warm air above the radiator upward toward the ceiling. There it drifts along the ceiling, becomes cooled, and settles downward along the walls of the room. In that manner *convection currents* are set up in the room, as shown by the direction of the arrows. Heat is transferred to the various parts of the room by *the intermingling of the heated masses of air with the cooler ones.* Air currents which creep in at the windows may help such circulation of air.

102. Why is convection so important? This method of transferring heat is extremely important because the circulation of the atmosphere over the surface of the earth depends almost entirely upon it. We learned in our earlier study that it is responsible, too, for the formation of land breezes and of sea breezes.

The ventilation of our houses is brought about by con-

vection currents. Let us use a box about 18 inches long, 12 inches wide, and 15 inches high to represent a room which we wish to ventilate. We may then bore two one-inch holes near the top-central portion of one end, and two holes near the lower-central portion of the opposite end. Then we may place a lighted candle inside the box, not far from the end which has the openings near the top. Smoke paper may be made by dipping a paper towel into a fairly strong solution of potassium nitrate, and then drying it. If a strip of such paper is ignited, and held just below the openings, the direction of the drafts set up by the heat of the candle inside can be seen by watching the clouds of smoke given off from the burning paper.

If possible, it is desirable to have a gentle cross-ventilation in a room. In planning a bedroom, one should have an opening near the top of one side of the room and an opening nearer the floor on the other side. The warm, less pure air of the room will then pass out, through the higher opening, at the same time that the colder, purer air will enter from the other side of the room, through the opening nearer the floor. The bed should be so placed that the sleeper will not lie in a direct draft. A draft may sometimes be avoided

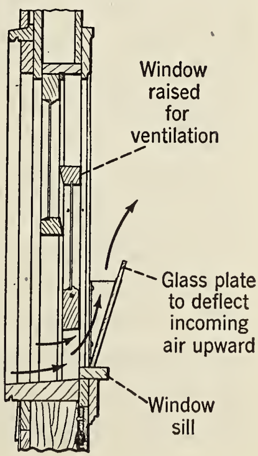


FIG. 5–10. In a double-hung window, the upper sash may be lowered and the lower sash may be raised. When both are opened for ventilation, the warmer air passes out through the upper opening and the fresh, colder air enters at the bottom. This colder air may be deflected upward by a glass plate to prevent a draft. How are the windows in your home built? Do you notice different types of windows in houses into which you go?

by turning the currents from the lower opening in an upward direction by means of a piece of plate glass or a board set as shown in Figure 5–10.

103. What is air conditioning? You probably eat about a ton of food in one year. Many persons also drink that amount of water. Does it astonish you to learn that the average person breathes more than six tons of air in one year?

We have inspectors to check the purity of our foods. Bread must be wrapped. Milk is pasteurized and then delivered in capped bottles, or in waxed containers. Many kinds of food have been wrapped in cellophane. Foods for sale are kept in cases where they are under refrigeration and where they are protected from flies. The handling of foods by prospective customers is discouraged.

Our water supply is checked in many ways. Purification at the source is attempted. Chemicals are used to destroy bacteria. The water is tested from time to time to see whether it is free from all things that might affect in any way the health of the person who drinks that water.

But what do we do about the air that we must breathe? You eat at a restaurant. The waitress is most careful not to touch any of your food with her hands. She is trained not to touch the top portion of the glass from which you must drink. But some thoughtless person at the next table lights a cigarette, puffs smoke toward you, and continues all through the meal to pollute the air which you are forced to breathe.

Can the engineer do something about conditioning the air? He finds that at least four things must be done if one is to be comfortable, efficient, and healthy:

a) The air must be warmed in winter and cooled in summer. It is possible for man to adapt himself to great extremes of temperature in the arctic regions or within the tropics, but he is most comfortable and he works most efficiently when the temperature range is from 63° F. to 75° F.

Provision is made for heating nearly all houses in the temperate zones in winter, but few homes are provided with cooling apparatus for summer use.

b) One often hears the expression, " It isn't the heat, but the humidity." If the relative humidity of a room falls much below 40 per cent, we have a desertlike atmosphere. The perspiration evaporates too rapidly and the skin feels dry. If the relative humidity rises much above 60 per cent, the perspiration evaporates from the skin so slowly that one feels " sticky " and damp. One feels more comfortable in a room if its relative humidity is kept between 40 per cent and 60 per cent. It is possible to save fuel if we keep in mind the fact that a reasonably humid room feels comfortable even when it is kept cooler than 68° F., which is usually considered a desirable room temperature. [See Fig. 5–11.]

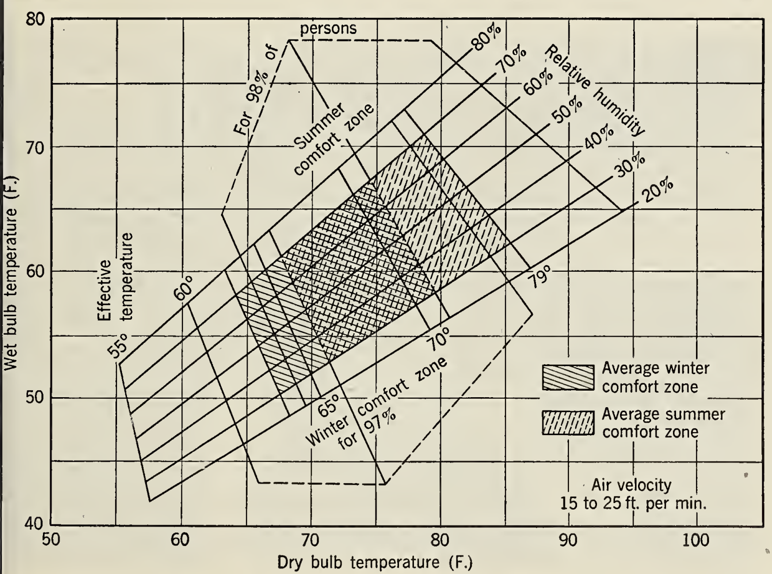


FIG. 5–11. This chart shows what weather conditions are needed to make a person feel comfortable. A room must not be too hot or too cold. The air in the room should not be too dry or too moist. How can you determine whether the air in a room is right for comfort?

c) The air may be filtered to make it relatively free from dust particles and bacteria that are always present in the air. Many diseases of the lungs can be traced to the inhaling of dust particles.

d) Even if the three things just mentioned are all taken care of, a person is not really comfortable unless the air is kept in constant gentle motion.

We know that it costs money to heat homes in winter. It is also costly to keep them cool in summer, since some form of refrigerating unit must be used. It is rather expensive, too, to make provision for adding moisture to the air in winter or for removing excess moisture in summer. These facts explain why air conditioning is not yet commonly used in homes. On the other hand, it is extensively used on trains, in theaters, in hotels, in restaurants, and in public buildings. [See Fig. 5–12.]

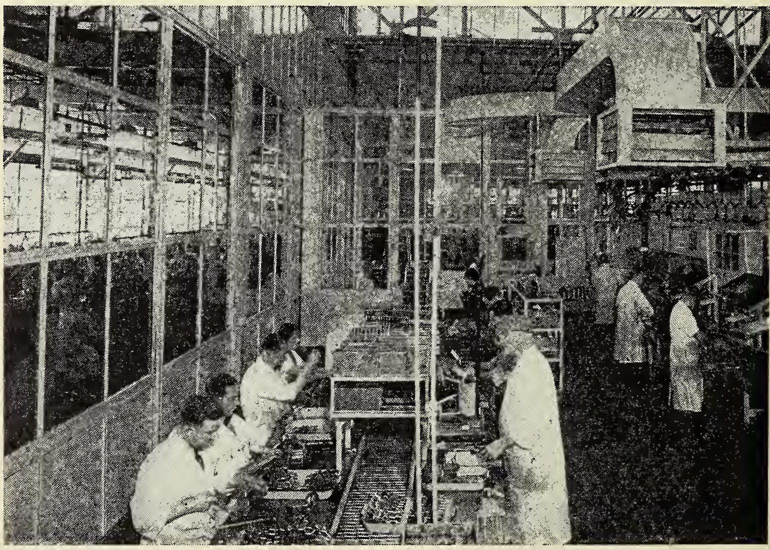


FIG. 5–12. Where a number of people are together as they are here, air conditioning is extremely helpful. One of the air-conditioning units which keep dust and dirt from this production line is shown in the upper-right corner of the picture. (*Courtesy Westinghouse*)

104. Heat travels by radiation, too. There is nothing between the sun and the earth's atmosphere to conduct heat to us. It is impossible, too, for heat to reach the earth by convection. Therefore there must be a third method by means of which heat is transmitted. We call this method *radiation.* Heat energy probably causes waves to be set up by the rapidly moving molecules of the heat-giving body. Such waves then transmit the heat energy to us. We hold our hand in the sun's rays. As the heat waves fall upon it, some of them are absorbed by the skin, and we have a feeling of warmth. As we stand in front of an open fireplace or a radiator, we receive heat energy given off by radiation.

105. How does radiant heat behave? We have learned that light travels more than 186,000 miles per second. Radiant heat comes to us from the sun at the same speed as light. The fact is proved by the cutting off of the sun's heat rays at exactly the same time that its light rays are cut off by the moon during a total eclipse of the sun.

As radiant heat passes through the air, some of it is absorbed. Such *absorption* warms the air through which the radiations are passing. The denser layers of air near the earth's surface absorb more heat energy than the rarer air at higher altitudes does. For that reason the air near the surface is warmer than is the air at higher altitudes.

What happens when radiant heat reaches the earth? Some of it is absorbed, thus warming the earth. Some of it is *reflected,* or turned back again, just as a rubber ball rebounds from a wall.

A highly polished surface, such as a mirror, is a good reflector of radiant heat. Because it reflects so much of the heat energy that falls upon it, a polished surface is a *poor absorber* of radiant heat. *Good reflectors of heat are always poor absorbers.*

The color of an object, too, has something to do with its ability to absorb heat. If we spread two pieces of cloth, one of them white and the other one black, over the snow on a

bright, sunshiny day, we find that the snow melts much more rapidly beneath the black cloth than it does beneath the white cloth. Black absorbs heat readily, but white reflects much of the heat it receives. From experience, you probably know that on a warm day a black coat feels warmer than a white one of the same weight and material. Black cinders or pieces of rock upon snow will cause the snow beneath them to melt more rapidly on sunshiny days. *Lampblack* is the best absorber of heat that is known. [See Fig. 5–13.]

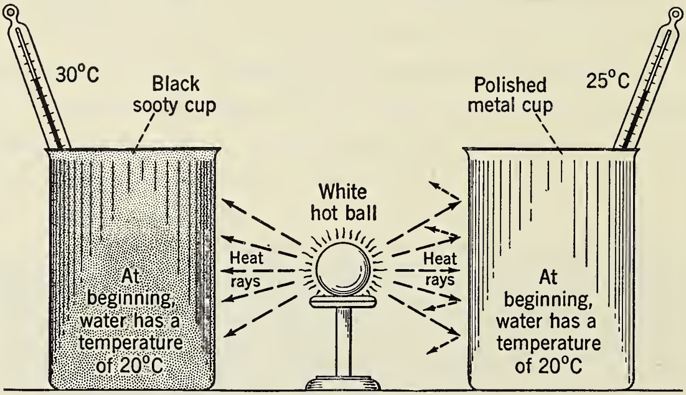


FIG. 5–13. A black sooty cup absorbs heat much faster than a polished metal cup does. The polished metal reflects heat rays.

It is true, too, that a *good absorber of heat also makes a good radiator.* Tea will cool off much faster when it stands in a teakettle with a roughened surface than it does when it stands in a teakettle whose outer surface is highly polished. A black, roughened surface is the best absorber of heat. It also radiates heat better than a white, smooth surface possibly can. Our steam radiators are made with roughened surfaces so they will radiate heat well. They would be even more efficient if they were painted with lampblack, but they would not be very artistic if they were so finished. When we paint our radiators a cream color, for example, we decrease their ability to radiate heat. [See Fig. 5–14.]

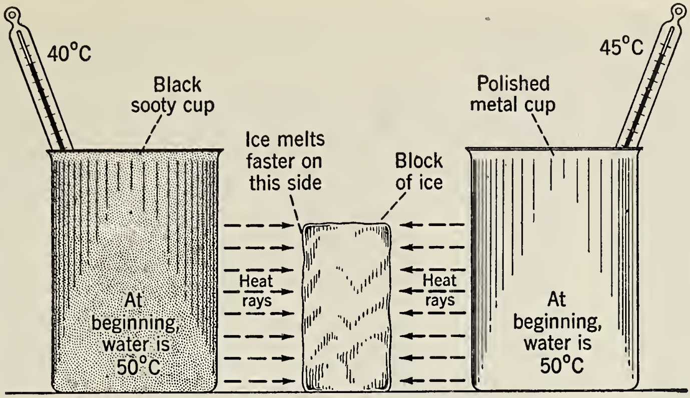


FIG. 5–14. Water in a black sooty cup cools faster than it does in a polished metal cup.

106. What heating system shall we install? There are several methods used for heating houses. The climate of the place governs the choice, to some extent. The locality of the place, and the kind of fuel that is available, also influence the choice. Our selection, then, will depend upon cost, convenience, and efficiency. Let us discuss briefly several systems that are in common use:

a) *Fireplaces.* In localities where wood is not too expensive, the fireplace is suitable for use in the spring and fall. It is not efficient enough to be used in cold climates in winter. It is excellent for use in supplementing the work of the furnace, and it can be used to take the chill off the house on cool days when the furnace is not in operation. [See Fig. 5–15.]

From the fireplace we get most of our heat by radiation. Unfortunately, most of the heat goes up the chimney, unless a *heatilator* (hēt′ĭ·lā′tẽr), or metal lining with double walls, is installed to direct warm air to various parts of the room. There is nothing more cheerful than an open fire in a fireplace, but the persons directly in front of it may get nearly all the heat, and their faces roast while their backs may be uncomfortably cold.

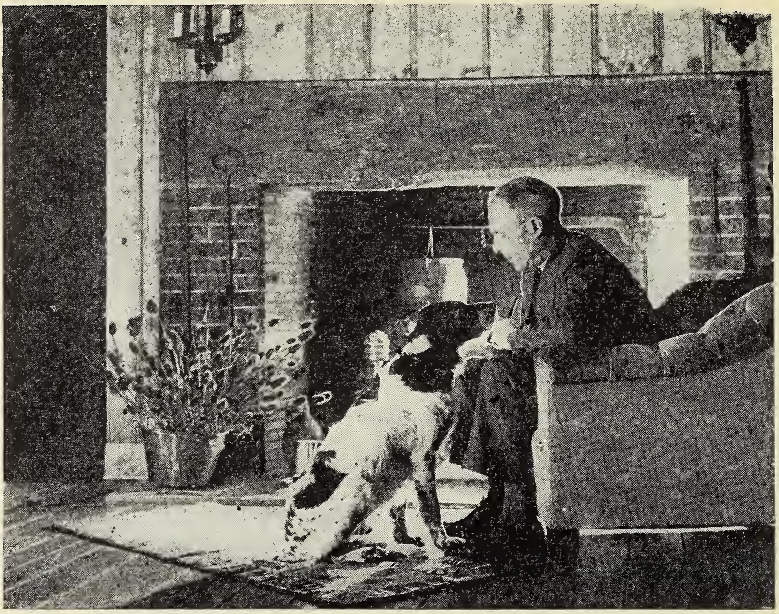


Fig. 5–15. Both human beings and animals enjoy a wood fire in a fireplace. Can you explain why fireplaces are not practical for heating? (*Boyer from Gendreau*)

b) *Stoves.* In many country homes and in some homes in the cities, there is no cellar beneath the house and there is no furnace for heating the entire home. Persons who live in such homes depend upon stoves in two or more rooms for their supply of heat.

From the stove, which may be heated with wood or coal, the room is warmed by convection and by radiation. The air around the stove is warmed and then pushed upward by the colder air near the floor. The air near the ceiling is likely to be overheated, and that near the floor is usually too cold. Heat is radiated from the sides of the stove, around which the family may group itself in cold weather. The amount of heat one gets decreases very rapidly as he gets farther from the stove as a source of radiant energy.

c) *Furnaces.* There are several heating systems in which

a furnace is used, but the inner workings of all types of furnaces are essentially the same. Look ahead to Figure 5–19. Upon the cast-iron grate the fuel is placed. Beneath the grate there is an ash pit into which the ashes fall as the fuel burns. The door leading to the ash pit is used for the removal of ashes, and it has several openings in it through which air containing oxygen may enter. The amount of oxygen which is admitted can be controlled by a sliding metal valve which regulates the draft. If the draft is open, air enters and passes up *through* the fuel on the grate, thus making it burn faster. The door to the grate can be opened for adding more fuel. It has a sliding draft, too, which may be closed, opened, or partially opened. It is called the *check draft* or *damper.* If the check draft is open, cold air is drawn in *over* the burning fuel. This cools the fire and makes it burn more slowly.

There must be a smoke pipe to connect the furnace with the chimney. A damper in the smoke pipe may be used to close partially the opening, and to prevent a considerable part of the heat from escaping up the chimney. In the following sections we shall see how furnaces are modified to meet the needs of certain heating systems and how the heat gets from the furnace to the rooms in each one.

107. The hot-air heating system. Let us take the furnace of Figure 5–16 and put a galvanized iron jacket all around it, being careful to leave considerable air space between the furnace and the jacket. In many hot-air furnaces the cold air enters from out-of-doors, and it is warmed as it circulates around the firebox, inside the metal jacket. The lighter, hot air is then pushed up into the rooms above the furnace, passing through metal pipes leading to the rooms. In the rooms the heat is distributed by means of convection currents. [See Fig. 5–16.] As the air cools, it leaves the rooms through cold air registers, whence it may pass directly out-of-doors or it may be returned through another pipe to the furnace to be reheated and returned to the rooms again.

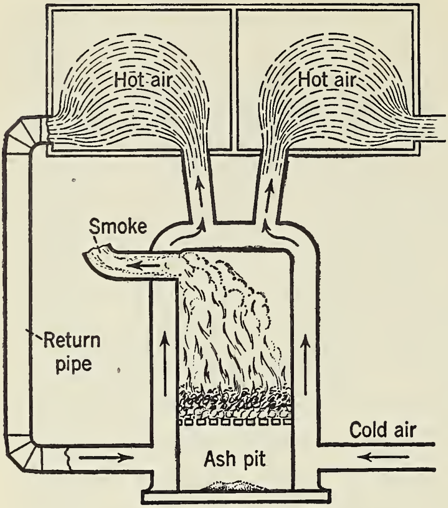


Fig. 5–16. The air from out-of-doors enters through the cold-air pipe or duct. It is warmed as it circulates around the furnace. Then it is pushed by the incoming cold air upward through metal pipes to the rooms above. The heat is transferred to the various parts of the house by convection.

In the *pipeless type* of hot-air furnace, the air circulates around the firebox, is heated, and then pushed upward to a large register in the floor of that room which is directly above the furnace. [See Fig. 5–17.] Thence it circulates around that room, and may possibly be sent to other rooms. After-

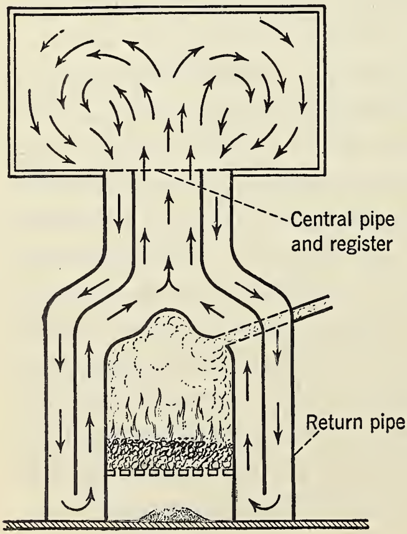


Fig. 5–17. In a pipeless hot-air furnace, such as the one shown here, the air is heated as it circulates around the firebox. Then it enters the room above the furnace, passing through a central register. The room is heated by convection. This type of furnace is suitable for cottages and small houses. Can you explain why it is not suitable for larger buildings?

ward it returns to the furnace to be reheated. The register has a central opening for the hot air, and a ring-shaped opening around it for the return of the cold air. Such furnaces are used extensively in cottages and small dwellings.

108. What are the advantages and the disadvantages of the hot-air furnace? The hot-air furnace is the cheapest type to install. It can be rather easily controlled in mild weather, when little heat is needed. One can start a fire and get heat more quickly than with other types of furnace. No radiators take up space. Air-conditioning units can easily be installed in connection with these furnaces.

The house cools off rather quickly after the fire is banked or after the fire goes out. Some dirt and dust are likely to be carried into the house through the hot-air pipes. With some hot-air-heating systems, it is difficult to heat all rooms equally. For example, a room on the windward side of the house may receive little heat, while a room on the sheltered side of the house may be overheated.

109. How does the hot-water furnace work? In this type of furnace, water circulates around the firebox much as air circulates in a hot-air furnace. Pipes from the furnace lead to radiators in each room of the house. The hot water loses much of its heat to the radiators. The radiators then transmit some heat to the room by radiation, but much more of it by convection currents that are set up around the radiator, as shown in Figure 5–18. At the far end of the radiator there is a return pipe to lead the partially cooled water back to the furnace to be reheated. The water circulates from the furnace to the radiators and back again by convection currents, because hot water is less dense than cold water. Since water expands considerably, an expansion tank must be used in connection with the heating system. Otherwise the pipes would burst or spring a leak.

110. What are the advantages and disadvantages of the hot-water-heating system? This type of heating system is efficient, but it is one of the most expensive systems to install,

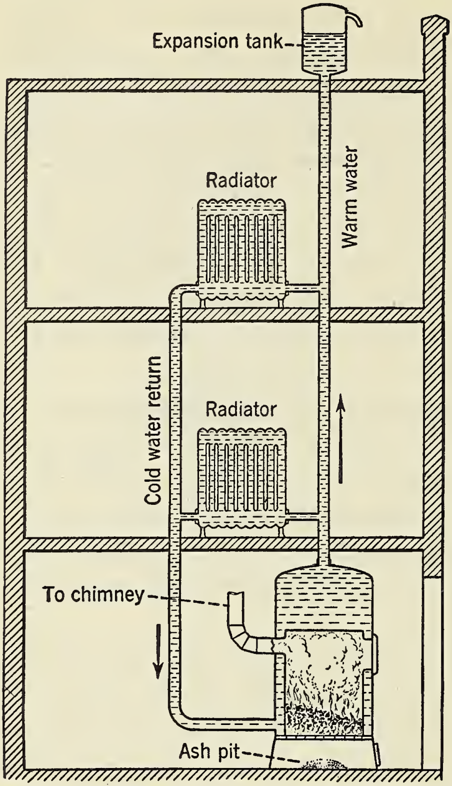


FIG. 5–18. In the hot-water-heating system, water circulates around the firebox, where it is warmed or heated. It then goes through pipes to the radiators. As it passes through the radiators it warms them by conduction. The radiators, in turn, warm the air above and around them by convection. A tank in the attic permits the water to expand as it is warmed. Without such a tank to take care of the increase in the volume of the water, the pipes and radiator might leak or even burst.

because the radiators must be large and there must be a pipe leading to the radiator and one leading from it. In the fall and spring, it is possible to have water from 90° F. to 100° F. circulating through the radiators. That is enough to take the chill off the house. In winter, the temperature of the water circulating through the house may be about 160° F.

The owner of a hot-water-heating system must take care to drain the water from the whole system if he closes the house for a few days in the winter. If the system freezes, the furnace walls may burst. Not only that, but the pipes leading to and from the radiators and the radiators themselves may also freeze and burst. If a thaw follows such a freeze before the owner returns, then the house will be

flooded from garret to cellar. The builder of a house which he plans to rent is not likely to install a hot-water-heating system.

111. How does a steam-heating system work? In the hot-water-heating system the furnace jacket, the pipes, and the radiators are all full of water at all times. In the steam-heating system, only a few gallons of water are added to the boiler, which is directly above the firebox. When this water is boiled, a part of it is converted into steam. Since one quart of water forms about 1700 quarts of steam, there is enough steam formed, when the water vaporizes, to expand and fill all the pipes and radiators. The steam is enclosed, and the pressure rises as the fire grows hotter. One or two pounds of steam pressure are usually sufficient to force the steam up into the radiators. [See Fig. 5–19.]

We have learned that it takes 540 calories of heat to vaporize one gram of water and convert it into steam. As that steam condenses in the radiators, each gram of it gives out 540 calories, which are radiated to the room or distributed to it by convection currents. In dwelling houses, no return pipe

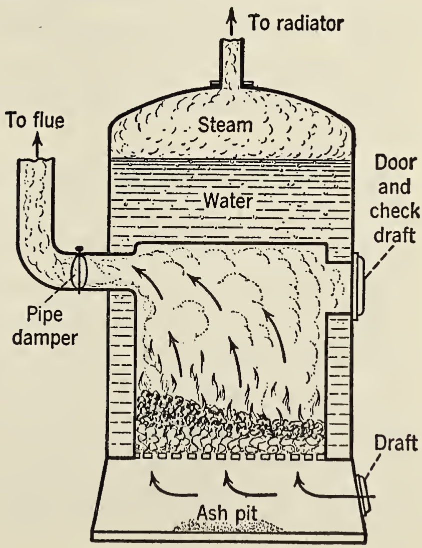


FIG. 5–19. Have you ever closely examined a steam-heating furnace? The door at the bottom is used as a draft, and for the removal of ashes. Ashes should be removed at least once a day when the furnace is in operation. Can you explain why? Part of the water in the furnace is converted into steam, which expands and circulates through the pipes to the radiators.

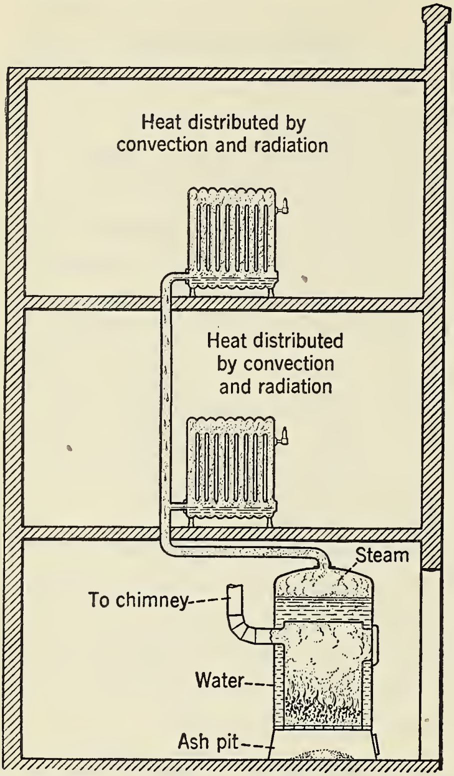


FIG. 5–20. In the radiators of a steam-heating system the steam condenses, giving out to the radiators and to the room 540 calories of heat for every gram of steam that condenses. As in the hot-water-heating system, the radiators receive heat by conduction and the rooms are warmed by convection; they are also warmed to some extent by radiation. Can you explain why a return pipe and an expansion tank are unnecessary in the steam-heating system?

is necessary, as the condensed water flows back to the furnace through the rather large pipe that leads to the radiator. [See Fig. 5–20.]

112. **Why is steam heating used extensively?** The cost of installing a steam-heating system is between that of the other two systems discussed. Steam heating is efficient, and rather easily controlled except in mild weather. Then one is likely to get too much heat or not enough. There is no heat in the radiators until the water begins to boil. There are radiators, too, to take up room, although they are not so large as those used for hot-water heating. The water in the boiler must be drawn off if the house is to be vacated for a few days in winter, or the water may freeze and ruin the boiler.

113. What fuel shall we use? A good fuel furnishes plenty of calories for every gram. It is not too hard to kindle, it does not burn up too rapidly, it is not too costly, it does not leave too much ash, and it does not give off soot or burn with a smoky flame. The most commonly used fuels are wood, coal, oil, and gas.

114. Is wood a good fuel? Wood burns with a rather clean flame and does not leave a great deal of ash. But most woods burn out fairly quickly, and the stove or furnace must be stoked frequently. The soft woods, in particular, burn rapidly. That includes the pines and firs, and such woods as cedar, sycamore, linden, and the poplars. Some woods, such as elm, ash, maple, beech, oak, and hickory furnish more heat units and burn out more slowly. In most parts of the United States so much land has been deforested that wood is now too expensive to be used as a fuel for heating a whole house.

115. Coal is a good fuel. *Soft coal*, or *bituminous* (bĭ·tū′-mĭ·nŭs) *coal*, is found in the majority of the states of the United States. It is one of the cheapest fuels that we have. Soft coal does not produce a great deal of ash, and it is rather easily kindled. It is rather difficult to burn soft coal without its producing a smoky flame and forming considerable soot. In industry, soft coal may be heated to get coal gas. The material which is left is known as *coke*, which burns with a hot, clean flame.

Anthracite, which is commonly called *hard coal*, is not found to any extent in the United States outside the state of Pennsylvania. It is much more expensive than soft coal. It burns with a clean flame, but it leaves a large quantity of ash. Hard coal is rather difficult to ignite, but it burns for a long time. It has a fairly high heat content; in other words, it produces a large number of calories per gram.

116. Shall we choose oil? If you are building a new house, you may want to install an oil burner. No grate is necessary for the furnace, but a special burner must be used. [See Fig. 5–21.] The burner evaporates the oil, which is ignited

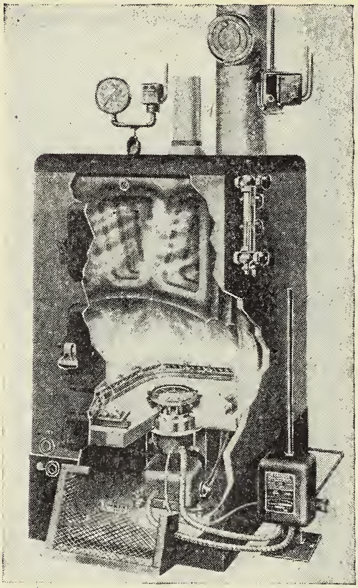


FIG. 5–21. It is very convenient to burn oil as a fuel. A thermostat starts the oil burning as soon as the room has become cooled below a temperature of your selection, and it cuts off the oil supply to the burner when the room is properly warmed. Oil heat usually costs more than coal heat, unless coal has to be shipped some distance. Under what circumstances might oil heat be worth the cost? What seem to you to be its greatest advantages? What difficulties might arise in connection with its use? (*Courtesy Timken Roller Bearing Co.*)

by means of an electric spark. Fuel oil burns with a hot flame, and it does not smoke if the burner is properly regulated. No ash is left. There is no stoking of the furnace, since the motor feeds the oil as fast as it is needed. In some localities, oil is a somewhat more expensive fuel than is coal. However, it saves the trouble of shoveling coal, removing ashes, and starting fires. It can be turned on at a moment's notice in the fall, or shut off instantly in the spring.

117. Gas is an excellent fuel. Many persons use gas as a fuel for cooking, but rather few persons use it for general heating. It is more expensive, as a rule, than oil or other kinds of fuel. It is often inexpensive in those localities where natural gas is found. Rates for artificial gas have been reduced in other places, too, and gas is becoming a real competitor with other fuels for heating the home. Its advantages are almost the same as those listed in part *b*, section 118.

118. What kind of range shall we put in the kitchen? (*a*) *The coal range.* In kitchens not supplied with other

heat, a coal range may serve the double duty of furnishing heat for the kitchen and for cooking purposes. It has certain inconveniences, such as the handling of fuel and removal of ashes. It is not expensive, however, and a coil may be placed in such a range to supply the house with hot water at little additional cost.

b) *The gas range.* Cooking by gas is one of the least expensive methods of cooking. It has the following advantages over the coal range: it can be turned on or off at a moment's notice; its heat is easy to regulate by turning the burner low, medium, or full; no more burners need be turned on than are needed; there is no fuel to carry, and there are no ashes to be removed; the heat is concentrated directly upon the vessel or skillet that is being heated; it gives a hot flame, and it is quicker than cooking with a coal range.

c) *The electric range.* Cooking by the use of electricity offers nearly all the advantages that one finds in cooking by gas. It is clean and convenient. It takes a little longer time to cook by electricity than by gas, but the heat is easily regulated. However, unless electricity can be purchased at a cost of only a few cents per kilowatt-hour, the use of elec-

FIG. 5–22. Twin electric ovens do their work well, in this modern stove. The surface heating units are regulated by a switch. Contrast the work of getting a large dinner today with the work of preparing a similar meal a hundred years ago. (*Courtesy Westinghouse*)

tricity for cooking purposes is not so economical as the use of gas or coal. [See Fig. 5–22.]

119. How does a gas burner work? No doubt you have used a Bunsen burner in the laboratory or at least examined one. As shown in Figure 5–23, you notice that it consists of a tube or barrel in which air and the fuel gas are mixed.

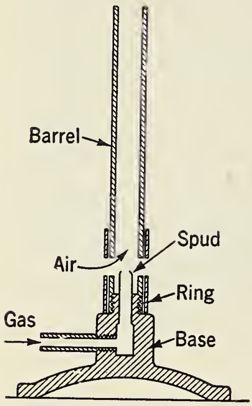
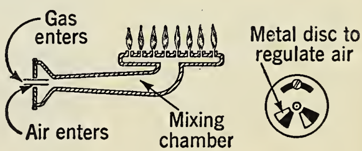


Fig. 5–23. Gas burns with a sooty flame unless it is mixed with some air before it burns. If too much air is mixed with the gas, it explodes in a manner similar to backfire of an automobile engine. The ring on the Bunsen burner is used to regulate the amount of air that enters.

The gas issues from the tip, or *spud*. The air enters through openings near the bottom of the tube. A ring around the tube may be used to close the openings, or partially to close them.

The burner of your gas range is modeled after the Bunsen burner. It is ring-shaped or star-shaped and there are several small openings from which the gas issues. In Figure 5–24 we see the mixing chamber used to mix some air with the fuel gas. The amount of air that enters the mixing chamber is controlled by the metal disc shown in the figure. If too little air enters, the gas flames will have yellow tips. This

Fig. 5–24. Check your gas burner at home. If the tiny flames have yellow tips, open the air holes a little. If the flame roars, close the air holes somewhat.



wastes fuel and also covers the bottom of the cooking utensils with soot. If too much air enters, an explosive mixture is formed. The flame roars a great deal, and it " pops " or " strikes back " and burns at the base of the burner, especially when the gas cock is partially turned off. A small set screw is used to hold the metal disc in position. To adjust the burner, one loosens the set screw, and then turns the disc until the flame burns with no yellow tips and no roaring. The set screw is then tightened to hold the disc in its proper position.

120. How can we have a supply of hot water? A coil in the kitchen coal range may be used to supply hot water for home use. A similar coiled pipe, either inside the furnace where it is exposed to the hot coals, or outside where steam can circulate around it, may also be used for the same purpose. Or, a separate coil, heated by gas, may be the

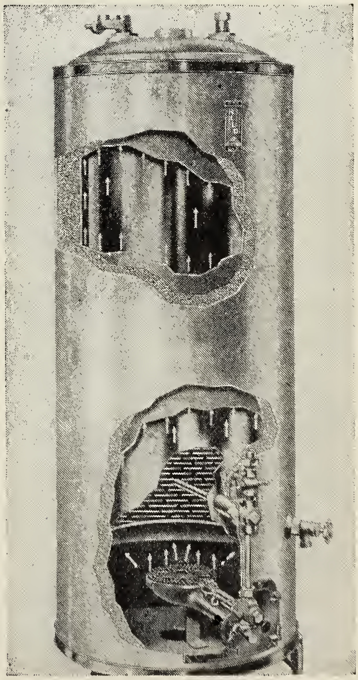


FIG. 5–25. Such a tank as the one pictured here is used to supply hot water for household use. The gas is turned on and off automatically by a device similar to that shown in Fig. 4–5, on page 92. Notice that the tank is thoroughly insulated. It costs quite a bit of money to heat water by gas, and the insulation saves its owner money by keeping the water hot for a long time. As the hot water is drawn off at the top for use, cold water enters through a different pipe which opens below the middle of the tank. (*Courtesy Ruud Manufacturing Co.*)

source of a hot-water supply. Let us study Figure 5–25 to see how the water is heated and stored for use as needed.

Cold water flows into the hot-water storage tank from an outlet, well below the middle of the tank. The hot water, as it comes from the heating coil, accumulates at the top of the tank. As hot water is drawn off from the top of the tank for use in the kitchen, bath, or laundry, more cold water flows into the lower part of the tank, coming directly from the water supply system. The water circulates through the hot-water heater by convection. Notice the direction indicated by the arrows.

QUESTIONS

1. Why does the handle of a silver teaspoon become hot so quickly if the bowl of the spoon is left standing in a cup of very hot liquid?

2. Which do you think would be warmer, two light blankets, or one heavy blanket equal in weight to the combined weight of the other two? Why?

3. Can you understand why workmen around furnaces wear woolen clothing?

4. Does clothing ever give us any warmth in winter? Explain your answer.

5. Why is black clothing so uncomfortably warm in hot summer sunshine?

6. Why is convection such an important method of distributing heat?

7. Is it economical to have radiators with rough surfaces? Is it economical to have them painted black? Explain your answers.

8. At what season of the year are sea breezes common along the seacoast? Why?

9. Do sea breezes occur in the daytime or at night? Why?

10. Why is an open fire in a fireplace so pleasing?

11. Why is a fireplace not efficient for heating a room?

12. When you build your home, what kind of heating system shall you want to install? Give all the reasons you can for your choice.

13. What fuel is used in your home? What are its advantages? What are its disadvantages?

14. What are the advantages of using gas for cooking purposes?

15. Explain how a blanket of snow protects the grass in winter.

16. Explain why cotton clothing is warmer than linen clothing.

17. In what ways do double windows help to save fuel?

18. What steps are necessary in air-conditioning a room?

Some things for you to do

1. Make a list of as many good conductors as you can find around your home.

2. Make a list of as many insulators as you can find in and around your home.

3. In your school laboratory you possibly have some device that can be used for measuring relative humidity. If so, measure the relative humidity of your schoolroom at a certain hour for each day of a week.

4. Make a sketch diagram of your furnace. Try to understand for what purpose each part is used.

Think about these!

1. Which furnished more of the materials used in the clothes that you are wearing — plants or animals?
2. What materials now used for making clothing were not used by our great-grandparents?
3. Are minerals used in any garments that you know of?
4. What material protects you from both heat and cold?

Words for this chapter

Rayon. An artificial fiber used as a substitute for silk.
Pyralin (pī′ră·lĭn). A plastic made from cellulose.
Bast. A strong woody fiber found in the stem of many plants.
Alkaline (ăl′kȧ·līn) **soap.** A soap containing an *alkali* (ăl′-kȧ·lī), or substance whose properties are opposite to those of an acid. Common lye is an example of an alkaline substance.
Lanolin lăn′ȯ·lĭn). A grease or oil obtained from wool.
Spinnerets. In insects, organs for producing thread, such as silk.
Cellulose (sĕl′ů·lōs). The tissue that forms the groundwork of all woody plants.
Bated. Treated to reduce swelling.
Emulsion (ė·mŭl′shŭn). A suspension of an oily liquid within another liquid.

CHAPTER 6 ______ UNIT 3

How Does Clothing Protect Us from Heat and Cold?

121. How is man superior to animals? We have already learned that man uses tools. He thinks and reasons better than other animals do. He is the only animal that uses fire to make himself more comfortable, to forge his tools, and to extract metals from their ores. Man builds a home for himself, and he clothes his body for comfort and protection.

It is true that some animals build dens or nests. Some of these nests are good examples of skill, too, but they do not compare very favorably with the houses which man builds for his comfort and enjoyment. Man is able to live on the icy shores of Greenland, or to make his home in the hot, moist climate of the Torrid Zone. The lion, king of beasts, or even the mighty elephant, would perish if taken to the polar regions. The huge polar bear is most uncomfortable in the zoological gardens of the temperate zones, and he may even perish in summer unless he is provided with a pool of cool water, with some pieces of ice added to it. [See Fig. 6–1.]

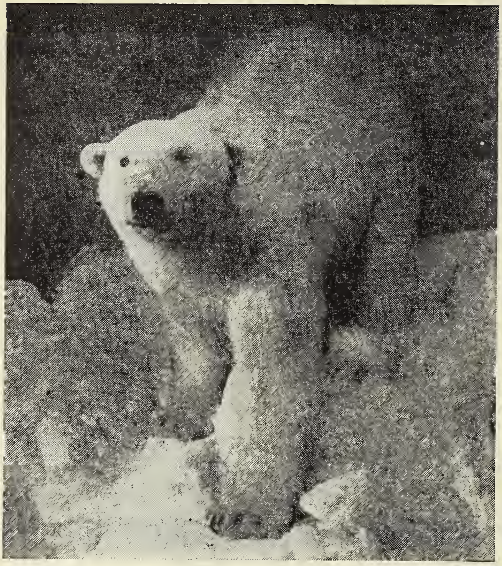


FIG. 6–1. The polar bear has a shaggy, creamy white coat which keeps him warm in the Arctic, his natural home. The coat is so thick that it makes him look even heavier than he is. Nevertheless, the polar bear is not uncomfortable during the summer in a temperate climate, such as ours, if he lives in a properly equipped zoo. (*American Museum of Natural History*)

How does it happen that man can live in either hot or cold climates and adapt himself to different climatic conditions? The answer is simple. He has learned how to build homes and heat them. He has learned how to provide a supply of food. He has learned how to make clothing to protect his body from the freezing cold or the withering heat of unfriendly climates.

122. What did our ancestors wear? Prehistoric man lived in caves, and it appears that he did not bother very much about clothing. As man became more civilized, however, he sought out various materials with which to clothe his body. In some cases large leaves, fastened together at the edges, were used to make crude clothing. Long grasses were used, too. They either hung loosely or they were woven or twisted together. Man took an important step forward when he learned how to remove the skins from animals and use them for clothing. The furs and skins used by the Indians and the Eskimos in making moccasins, clothing, and coverings are excellent for keeping the body warm in winter. [See Fig. 6–2.]

FIG. 6–2. This young Eskimo wears a suit and boots made of skin. They are made with the fur inside, as you can see by the collar of fur. (*Courtesy Alaska Steamship Co.*)

Man then learned how to spin a continuous thread of almost any desired length. He did this by twisting together plant or animal fibers. The art of weaving the threads into cloth then followed. The weaver learned how to intertwine separate threads in order to make cloth or fabric. In some such manner the *textile* industry, or industry of weaving, was born. Let us find out what is the source of various fibers used by this industry.

123. Why do we say, "Cotton is king"? In some of our southern states, cotton is one of the most important farm crops. The plant is grown, too, in Mexico, Egypt, and India, and in other parts of the world. In southern United States, most seed is sown in April. The plant grows rather quickly and begins to bloom some time in June. After six to eight

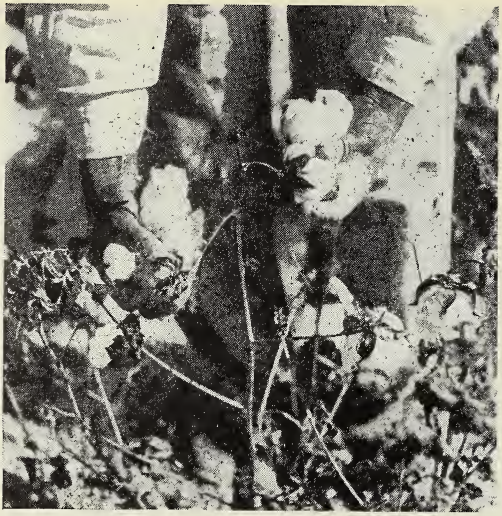


FIG. 6–3. Cotton begins to bloom in the early summer. When the blossom first appears, it is yellowish-white in color. The next day it turns reddish-purple. By late summer the cotton is ready to be picked. There may be two or three pickings, for all the bolls on a plant do not ripen at the same time. (*FSA photo by Marion Post-Wolcott*)

weeks the cotton *capsule,* or bag-shaped fruit, ripens and splits open, and the fluffy white *boll* (bōl) of cotton fibers is soon ready to be picked. [See Fig. 6–3.]

The cotton fibers which are used for spinning are attached to the seed and must be separated from it by the use of the *cotton gin* (jĭn), an invention of Eli Whitney. A valuable oil is pressed from the seed of the cotton after the fiber is removed. Cottonseed oil is used in making shortening and salad oils. Cheaper grades of the oil find use in making soap. Cottonseed meal is used as a food for farm animals.

In the *upland* variety of cotton, the fibers vary from one-half an inch to less than one inch in length. They are known as *short-staple* fibers. The best cotton is the so-called *sea-island* cotton. Its fibers are fairly uniform, and they may run from one and one-half inches to two inches in length. They are used in making the finest cotton fabrics.

124. What are the properties of cotton fibers? Let us put a few cotton fibers on a glass slide and examine them with a compound microscope. We find that the fibers are flat and twisted. [See Fig. 6–4.] Because the fibers have

FIG. 6–4. Cotton fibers appear flat and twisted, when they are viewed with a compound microscope. When such fibers are spun into a thread, they do not ravel so easily as do some of the other fibers, such as linen and silk.

this shape, they are easily spun into thread, even if they are rather short.

The fiber of the cotton plant is fairly strong, and it wears well. It gives off more lint than linen fibers do. It shrinks somewhat when it becomes wet. It is not injured by boiling water. It decays slowly.

Cotton fibers are completely destroyed by *hydrochloric* (hī'drŏ·klō'rĭk) *acid,* but they are not affected very much by a solution of *lye* or of *sodium hydroxide.* If the solution of sodium hydroxide is very strong, or concentrated, cotton fibers shrink decidedly when submerged in it.

125. Why is cotton so extensively used? There are several reasons why cotton is widely used for making fabrics of many kinds:

a) Cotton fibers are fairly strong.

b) Cotton fibers are durable, and they wear well.

c) Cotton fabrics are not easily injured by laundering.

d) Cotton fabrics may be bleached easily, and they can then be used for white goods, or they may be dyed any desired color.

e) Cotton fibers are the least expensive fibers used for fabrics.

f) Cotton is a fair insulator, but it is not too heavy to be used for making clothing for use in warm climates.

g) Cotton fabrics have a pleasing appearance.

There are more than three times as many persons in China as there are in the entire United States of America. India

has more than twice the population of the United States. In both India and China, cotton clothing is more extensively worn than clothing made from any other fibers. In Europe and the United States, cotton is extensively used for clothing. Clothing may be made from pure cotton, or the cotton fibers may be interwoven with silk, linen, or wool.

Cotton is widely used in making draperies, sheets, pillow cases, towels; and for such medical supplies as cotton bandages and absorbent cotton. During a period of low prices, cotton has been used as a binder in making concrete roads.

126. What products are made from cotton? Cotton not only is used for making cotton goods, but also is used as a raw material in the manufacture of other products. We shall mention a few of them:

a) *Mercerized cotton* was first produced by John Mercer, who observed that cotton shrinks to about three-fourths its length when it is immersed in a concentrated solution of sodium hydroxide, or common lye. He stretched some cotton fabric on a frame so that it could not shrink. Then when he immersed the fabric in a strong solution of lye, he found that the cotton became more lustrous and silky in appearance. Cotton fibers so treated are called *mercerized cotton.*

b) *Smokeless powder,* which produces very little or no smoke in exploding, is made by treating cotton with a mixture of nitric and sulfuric acids.

c) *Rayon,* a silk substitute, can be made by treating cotton with certain chemicals in order to make it dissolve, or go into suspension. The dissolved cotton is squirted through tiny openings to form threads that have a silky luster.

d) *Plastics* are substances which can be pressed, blown, drawn, or molded into some desired shape. Some plastics are made by treating cotton with a mixture of nitric acid and sulfuric acid, in much the same manner that smokeless powder is made. Sometimes other acid is used instead of the nitric acid. One company that makes such a plastic calls its

FIG. 6–5. Nylon is made in various diameter sizes. The strands pictured here are much too large for women's stockings; they will be used for such things as brush bristles. (*Courtesy E. I. du Pont de Nemours*)

product *celluloid* (sĕl′ū·loid). A similar product made by another company is called *pyralin*. Such products may be fashioned into combs, brushes, backs for mirrors, and many similar articles. [See Fig. 6–5.] *Motion-picture film* is made from a plastic in which cotton is treated with nitric acid or with acetic (ă·sē′tĭk) acid. Cellophane (sĕl′ō·fān) is made in a similar manner from cotton. As you doubtless know, cellophane is used to wrap almost anything, from razor blades to automobiles.

127. What is the source of linen? Long, strong linen fibers are obtained from the stalks of the *flax* plant. Some flax is grown in the United States, but in normal times the bulk of our linens have come from Russia, Ireland, Scotland, Belgium, and Germany.

Flax is an annual, flowering plant which grows to a height of from two to three feet. The stem is slender and free from branches. The long *bast* fibers of the flax plant form the linen of commerce. The most useful fibers surround the inner, woody portion of the stem, and are enclosed in a hard outside layer.

If a fine linen thread is desired, the slender stalks are harvested before the seed ripens. Coarser threads are produced by the time that the seeds approach maturity. When coarse, strong fibers are needed, the flax plant is permitted to grow until it matures fully. In such cases, a crop of flaxseed is also obtained. Linseed oil, which is so largely used in the paint industry, is obtained from the seed of the flax plant.

*128. **How are linen fibers separated from the stalk of the flax?** The method used to separate the fibers from the stalk varies in different countries. In all cases, however, the plant is pulled up by the roots, and the leaves and seeds are removed by a process called *rippling*. The stalks are then soaked in a pool or stream for from ten days to two weeks. Bacteria present in the water cause them partially to decompose. This process, which is called *retting*, is continued until the linen fibers may be easily separated from the other portions of the stem. The beating process by which the fibers are separated from the woody part of the stem is known as *scutching*. The coarse, broken fibers are marketed as a product known as *tow* (tō). A process which is called *hackling*, or *combing*, is used to separate the fine, long, linen fibers from the tow. After the combing process, the fibers are ready for *spinning*. From the spinning wheel, they go to the loom for *weaving*.

129. **What are the properties of linen fibers?** Let us examine some linen fibers by means of a compound microscope. [See Fig. 6–6.] You observe that they are round and smooth, although some of them are pointed at the ends, or at one end. You note, too, that there are enlarged portions at intervals. Such knoblike portions help to keep the smooth

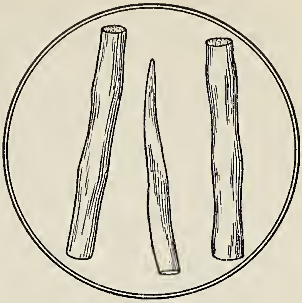


FIG. 6–6. When linen fibers are seen under a microscope, they appear as long and cylindrical, but there are enlarged portions at certain places, like the sticks of candy known as "chicken bones." Some of the fibers are pointed at one end, but others are blunt.

linen fibers from separating easily after they have been spun or woven.

Linen fibers are completely destroyed by cold hydrochloric acid, but they are not much affected by lye or by sodium hydroxide. Linen fibers are much like cotton fibers in the ease with which they are attacked by different chemicals.

Linen fibers are very strong. Since they are smooth, the goods made from them do not soil easily. Neither does linen leave much lint. If table napkins cover a suit of clothes with lint, they probably contain considerable cotton. Suits made from linen hold their shape well. Linen launders well, and a freshly ironed linen fabric is glossy and beautiful.

130. For what purposes is linen used? Every housewife likes to have fine table linen. When properly bleached, linen napkins and tablecloths are snowy in their whiteness. Although we often speak of *bed linen,* the great majority of housewives use cotton sheets and pillow cases instead of linen ones. Tea towels and hand towels are sometimes made of linen. The finest Belgian laces are made from linen thread. Irish linens, too, are famous for their fine quality.

Because linen fibers are strong, they make excellent thread. The coarser linen fibers are used to make wrapping twine.

Linen fibers are better conductors of heat than are cotton fibers. For that reason, linen clothing is cooler in summer than cotton clothing, unless it is worn in direct sunlight. Linen is too good a conductor of heat to be worn in winter.

131. What other plant fibers are used by man? Several other plants produce fibers which man finds useful. We may mention some of them briefly.

a) *Hemp* is a tall plant grown to some extent in the United States, but more extensively in Russia and in the Philippines. The bast fibers of hemp are exceedingly strong when dry, and they are not weakened to a great extent even when they get wet. Some fibers are not so strong when they are wet. Hemp fibers, which decay slowly, are used in making strong twine and rope. Sometimes they are woven to make canvas for tents, although canvas may be made of either cotton or linen, too.

b) *Jute* comes from a plant which is grown in east India. It is strong, but it rots quickly when it gets wet. Jute is used for making burlap, which may be used in the manufacture of strong bags for holding potatoes, fertilizer, and other farm products. Burlap is frequently used to form the base for linoleum.

c) *Ramie* (răm′ē) is an Asiatic plant which produces a very strong fiber used to make fabrics resembling linen.

d) *Kapok* (kā′pŏk), or tree cotton, is a silky fiber which is too short to be spun into thread. It finds use for filling mattresses and pillows. It is used, too, for stuffing life preservers and the cushions of motor boats. A kapok cushion will keep a person afloat.

132. What is the source of wool? If you have ever seen sheep, you know that they are almost entirely covered with fine, long hair that varies in length from an inch and a half to several inches. [See Fig. 6–7.] The length of the wool fibers and also their fineness depend upon the variety of the sheep. The Merino sheep, for example, is a superior wool-producer, because it has a particularly heavy fleece. The Merino sheep is small, however, and it is not a satisfactory meat-producer. Some farmers breed a larger variety of sheep, such as the Shropshire, Southdown, or Cotswold. They are valuable for both wool and meat. [See Fig. 6–8.]

FIG. 6–7. These Merino sheep stood for the photographer in their ıative Australia, where the finest wool in the world is produced. Ausralia is first among wool-producing countries, although many of the arly settlements on the continent were made by people who had been ttracted there by the hope of discovering gold. Notice the alert and esponsible sheep dog watching the flock in this picture. (*Courtesy* *ıustralian News and Information Bureau*)

FIG. 6–8. The comortably clothed sheep in his picture is a champion hropshire ewe. The hropshire sheep is one of he most popular mutton heep in the United States. *FSA photo by Rothstein*)

Fig. 6–9. The fleece which has kept this young sheep warm through the winter has just been clipped from it; but the sheep does not seem to be depressed or disturbed. Another fleece will grow before the next winter. (*FSA photo by Rothstein*)

*133. **How is wool prepared for spinning?** At least once a year the fleece is clipped from the sheep. [See Fig. 6–9.] The wool is carefully washed, either before it has been shorn, or afterwards, in order that it may be free from dirt and perspiration. A weak *alkaline soap* is sometimes used for *scouring* the wool. A grease known as *lanolin* is obtained

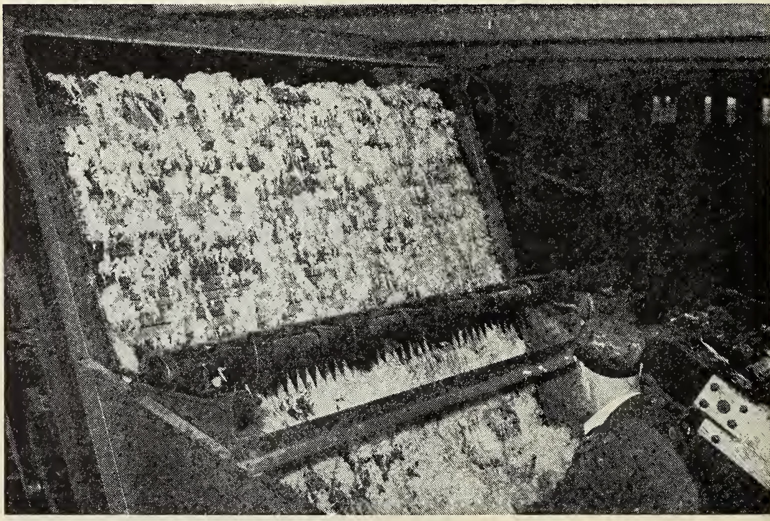


Fig. 6–10. Cleansed wool entering a drying chamber at a wool-scouring plant. (*FSA photo by Lee*)

from the wool fibers. This grease is used in making salves and ointments. It is a valuable grease, because it mixes fairly well with water. The wool perspiration contains some potassium compounds which are useful as plant fertilizers.

After the wool fibers have been thoroughly cleansed, they are *carded*, or *combed*, to disentangle the fibers and to arrange them in order for spinning and weaving. [See Fig. 6–10.]

134. What are the properties of wool? Let us examine some wool fibers by means of a compound microscope. We find that they are scaly in appearance. When the wool is spun, the scales tend to interlock with one another and thus make a stronger thread. Wool fibers are elastic and springy. For that reason a woolen garment holds its shape fairly well. [See Fig. 6–11.]

FIG. 6–11. Wool fibers are scaly when we see them by the aid of a microscope. That makes them easy to identify. The scales help to hold the fibers together when they are spun into yarn and woven into cloth.

Wool absorbs water readily. Care must be taken when laundering a woolen garment to prevent shrinkage. Too hot water is likely to cause shrinkage, and too harsh soap may also cause it. Heat has a tendency to make woolen fibers brittle. Care must be taken not to permit a woolen garment to get hotter than 100° F., or about the temperature of the body. Woolen fabrics should not be boiled in the laundry.

Wool is not affected by cold hydrochloric acid. In fact, matted wool is sometimes treated with hydrochloric acid to destroy the fruits of the burdock with which the wool may have become snarled and matted. Wool fibers take dyes

readily. Great care must be taken in the bleaching of wool to prevent the fibers from being injured by the chemicals that cause the bleaching. Even a five-per-cent solution of sodium hydroxide, which has no effect upon cotton or linen, will destroy wool completely, if it is warmed slightly.

135. Why is wool so important? Wool fibers are fairly strong, and a suit of clothes made from *virgin wool* will last a long time, if it is cared for properly. The term *virgin wool* means that the wool has never before been used in any garment or for any other purpose. The twisted wool fibers have many air spaces between them. For that reason wool is a poor conductor of heat, and it does not permit the heat from our bodies to escape readily in cold weather. Hence woolen clothing feels warmer in winter than cotton or linen clothing. Wool is used, too, in making rugs, carpets, draperies, robes, and furniture coverings.

136. What are some different grades of wool? The term *pure wool* does not necessarily mean that the wool is of the highest quality. It does mean that no cotton or other fibers have been interwoven with wool.

Wool is so valuable that it is often reclaimed from old garments. A garment may be badly worn; or possibly the style has changed, and a garment is cast aside. Of course some of the wool fibers are broken in the reclaiming process of shredding and picking the fibers apart, but some of the wool fibers in it may be recovered.

Because some of the fibers are broken in the reclaiming process, a suit of clothes made from *reclaimed wool* will not wear so long as one that is made from virgin wool.

Fluffy, fibrous material obtained from the carding process or from the reclaiming process is sometimes woven into woolen suits. Such material is known as *shoddy*. As one might guess, a suit containing shoddy has very poor wearing qualities.

***137. What other animal fibers are used?** Wool is not the only animal fiber that is used for spinning and weaving

into cloth. The hair from any animal may be used, provided it is not too coarse or too short.

a) *Cashmere* is made from the hair of a goat that lives in the Himalaya (hĭ·mä′lȧ·yȧ) Mountain regions. Beneath the long hair of the goat is an undercoat of wool which is particularly soft. Imitation cashmere is made from sheep's wool.

b) *Mohair,* which finds considerable use in making upholstered furniture, is made from the silky hair of the Angora goat. Mohair is very durable. A cheap substitute made of cotton and wool is sometimes used for mohair.

c) *Alpaca* is a fabric which is made from hair of the animal of the same name. The alpaca is one kind of *llama* (lä′mȧ), an animal which lives in the high Andes Mountains in South America, especially in Peru. [See Fig. 6–12.]

FIG. 6–12. You probably know how wool is obtained from sheep, but how do you suppose the hair is taken from llamas, such as the ones shown here? (*Courtesy Grace Line*)

d) *Camel's hair* finds some use in making soft, warm, lightweight overcoats and sweaters, which wear a long time.

e) *Rabbit's fur* finds considerable use in making the felt used for men's hats. As a fur, it is not very durable.

138. What is the source of silk? Natural silk is spun by the silkworm as it forms its cocoon. The silkworm is not a true worm, but a caterpillar, which represents the *larval* stage in the life-history of the silkworm moth. This moth lays her eggs, usually on the leaf of a mulberry tree. When the *larvae* first hatch, they are very tiny, not more than a quarter of an inch in length. But during the thirty days which the caterpillar lives, it eats like a glutton, and grows to a length of about three inches. Its weight increases several thousand times during that time. Then the caterpillar stops eating and becomes sluggish. Through two tiny glands, or *spinnerets,* it then begins to spin a double thread to form a *cocoon.*

In getting the silk, the raiser of the silkworms heats the cocoon to kill the larva inside, and soaks the cocoon in water to soften the silk glue which holds the threads together. Then he unwinds the silk thread of which the cocoon was made, and winds it upon a reel. A single thread of silk may be from 800 yards to 1000 yards in length, or approximately one-half mile. It takes thousands of cocoons to supply enough silk for a single dress.

139. What are the properties of silk? Suppose we examine a few silk threads by the aid of a compound microscope.

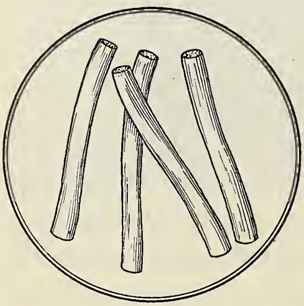


FIG. 6–13. Silk fibers which are examined by the aid of a microscope appear round and smooth. They do not have any knotlike parts, as linen fibers do.

[See Fig. 6–13.] We notice that the silk thread is smooth and round. It seems to be of uniform diameter through its entire length.

Silk fibers are exceptionally strong. A silk fiber will sustain a load nearly as great as that which can be sustained by an iron wire of the same diameter. Silk takes dyes easily. The smoothness of silk fiber and its sheen give to silk its beautiful appearance.

Silk dissolves slowly, but completely, in hydrochloric acid. It is easily destroyed by sodium hydroxide. Silk fibers are also completely destroyed by Javelle (zhȧ·vĕl′) water, a solution which is often used to remove spots and stains from clothing made of other materials.

In the dyeing of silk, the fibers are sometimes loaded or weighted with certain chemicals, especially with the salts of tin. Such weighting material soon decreases the strength of the silk fiber. For that reason, a weighted silk fabric will cut or break more quickly than unweighted silk. Enough weighting is sometimes added to cause the silk fibers to break through when the cloth is creased. Silk threads are also weakened by excessive perspiration.

140. Why is silk so important? The silk industry is thousands of years old. Silk cloth has been made in China and Japan for many centuries. Travelers smuggled the eggs of the silkworm moth out of the Orient into France and Italy. Since that time, the production of silk has been an important industry in those countries. It is estimated that it takes 5,000,000 families to carry on the work of producing silk in China and Japan. The silkworms have to be fed from 20 to 30 times a day. More than 2000 worms are needed to produce one pound of silk, and they must be fed abundantly. It is claimed that one ounce of newly hatched silkworms will eat 40,000 times their own weight of mulberry leaves in thirty days. [See Fig. 6–14.] You can understand that the labor involved in feeding the silkworms must be very great; and so, too, is the labor of treating the cocoons to soften the

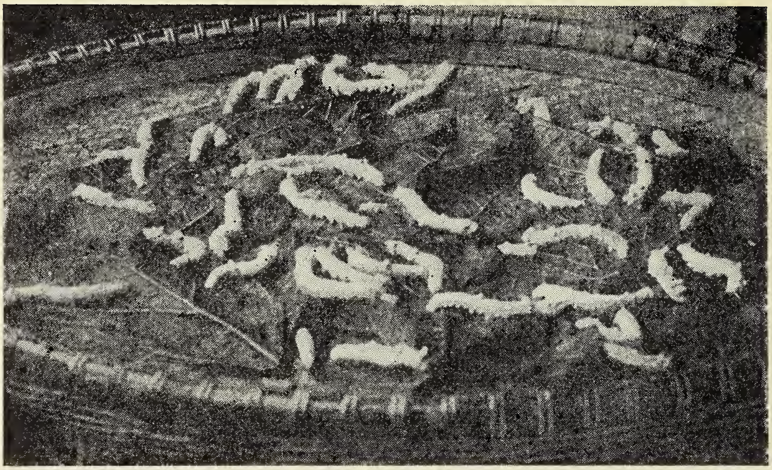


FIG. 6–14. Despite many efforts — including an attempt by Benjamin Franklin — the raising of silkworms has not succeeded in this country. (*Courtesy Western Electric Co.*)

silk, and of reeling the silk. It is not astonishing that raw silk has sometimes cost from \$6 to \$10 per pound.

The amount of silk used in weaving stockings and hosiery is large. Silk fabric is also used for dress materials, ribbons, curtains, and draperies. A considerable quantity of silk is used for insulating electric wires.

141. How can one tell the different fibers apart? The most satisfactory method of telling one fiber from another depends upon the use of the microscope. It is more reliable than any other test. Some other ways in which fibers can be distinguished from each other are described below.

a) *Animal fibers and plant fibers.* The plant fibers, both cotton and linen, are completely destroyed by cold, concentrated hydrochloric acid. Wool is hardly affected by cold, concentrated hydrochloric acid, although silk is destroyed by it.

Both silk and wool are easily and quickly destroyed by a five-per-cent solution of sodium hydroxide. Neither one of the two common plant fibers is attacked by such a solution.

Wool may be distinguished by the odor of burning hair which can be detected when wool is burned.

b) *Cotton fibers and linen fibers.* It is almost impossible to distinguish cotton from linen by any chemical test. New linen is more slowly attacked by cold concentrated sulfuric acid, but the difference disappears after the linen has been laundered a few times. A little more light passes through an oil spot on linen than through a similar spot on cotton. Cotton fibers also give off more lint than linen fibers do.

c) *Wool and silk.* Suppose we have two fibers that we are trying to identify. If both dissolve readily in a dilute solution of sodium hydroxide, they are animal fibers. If we put both of them in cold, concentrated hydrochloric acid, and one of them is destroyed, then we know that the one that was destroyed was silk. The other one must have been wool.

142. What is rayon? The feeding of silkworms and the making of silk from their cocoons is a laborious and an expensive process. For that reason, man attempted to imitate the silkworm, and he has succeeded remarkably well. He has worked out methods of spinning silky fibers which resemble silk and may be substituted for silk. The product is not really silk, and it is incorrect to call it *artificial silk.* The name *rayon* has been given to some of the silk substitutes made by man, although several different methods of making them are in use. [See Fig. 6–15.]

143. How is rayon made? The raw material used in making rayon consists of *cellulose,* the woody fiber found in plants. The cotton fiber is nearly pure cellulose. For making rayon, those short fibers known as *cotton lint* may be used. Wood pulp consists largely of the cellulose from which paper is made.

Several methods of making rayon are in use, but in each method it is necessary to get the cellulose into a solution or suspension from which it can be spun into threads. In the *viscose* (vĭs′kōs) process, the cellulose is treated with sodium hydroxide and another chemical, carbon disulfide. These

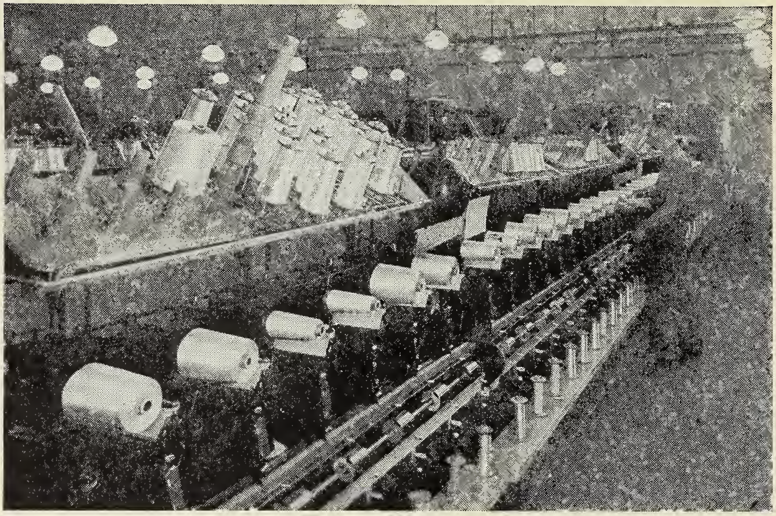


FIG. 6–15. The future of rayon is, of course, unknown. But from the tremendous annual production today, it is safe for us to assume that it will continue to be produced at a rapid pace for at least several years. (*Courtesy E. I. du Pont de Nemours & Co.*)

chemicals convert the cellulose into a thick solution ready to be spun into thread.

The spinning process is most ingenious. For the *spinnerets* man probably got his ideas from the spinnerets of the silkworm or the spider. The man-made spinnerets consist of thin metal discs, made from a mixture of gold and platinum. In each disc there are twenty or more holes, each having a diameter less than two ten-thousandths of an inch. The spinnerets are mounted at the end of a tube in such a manner that the viscose solution can flow through the tiny holes in the discs. [See Fig. 6–16.]

Anyone watching the spinning process can well imagine that he is seeing a miracle. The clear viscose solution flows through the tiny openings of the discs in the spinnerets into another liquid, often some acid. As soon as the viscose touches the other liquid, it changes into a tiny thread. The tiny threadlets precipitated by the acid solution are picked

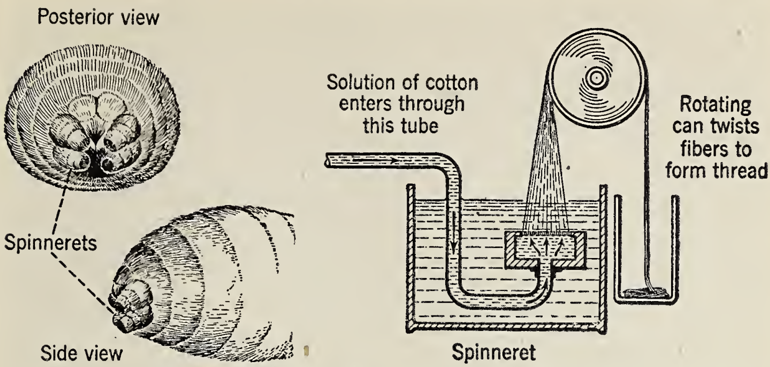


FIG. 6–16. The six spinnerets on the rear of the spider produce a natural thread. Man has copied the spider's method and has produced rayon threads by using an artificial spinneret.

up and twisted together to make a single thread of rayon.

144. What are the properties of rayon? The fibers of rayon which are made by the method just described are smooth and round. They have a shiny appearance, because they can reflect light much as a mirror does. They resemble silk in luster and appearance. They can be treated so that they appear even more lustrous than natural silk, or they can be treated so that they will be less glossy. When they are dry, rayon fibers are nearly as strong as silk fibers, and they wear well. They are rather easily broken when they are wet, and care must be taken when wringing rayon fabrics in the laundry to prevent the breaking of the fibers. It is almost impossible for the average person to tell rayon from silk.

145. How can rayon fibers be identified? Since rayon is made from cotton or cellulose, it is similar to cotton in its behavior. For example, it does not dissolve in sodium hydroxide. It is dyed in the same manner that cotton goods are dyed. Rayon is destroyed by hydrochloric acid. If we have two samples, one of rayon and one of silk, we may find out the identity by placing both of them in a hot, five-percent solution of sodium hydroxide. The silk is destroyed, but the rayon is not affected.

146. Are there other silk substitutes? *Celanese* (sĕl′-ȧ·nēs) is a kind of rayon. Like rayon, celanese is made from cellulose. In the making of celanese, the cellulose is treated with acetic acid. This particular acid is present in a dilute solution (four per cent to six per cent) in ordinary vinegar. Celanese resembles silk in both gloss and luster.

Nylon (nī′lŏn) is a new product which was exhibited by the du Pont chemical company at the World's Fair in New York. It is strong, and it resembles silk in appearance. Many girls have learned to their sorrow that a " run " develops quickly when one thread in a silk stocking is broken. Stockings made from Nylon are not guaranteed to be " run-proof," but those who wear them say that it takes a more severe snag to start a " run " in them.

If the chemists keep on turning out silk substitutes, the poor little silkworm is likely to find himself out of a job. But that is not the whole story. In normal years, the United States imports many million dollars worth of silk from Japan. If Nylon proves to be as satisfactory as it now promises to be, our factories will be making silk substitutes in ever-increasing quantities to replace the natural silk.

147. Where do we get fur? When the United States and Canada were first settled, fur-bearing animals were numerous. Trapping became an important industry, especially in the Hudson Bay region. Fur-bearing animals may be found almost anywhere in the world, but, as a rule, animals that live in very cold climates have superior fur to that of animals which live in warmer climates. The fur is thicker.

Among the fur-bearing animals, we find the seal, the beaver, the otter, the mink, the marten, the skunk, the weasel, the wolf, the raccoon, the muskrat, the squirrel, and the fox. The fur of the fox is long and beautiful, although it does not wear so well as some harsher, wirier furs. Fox farms, on which foxes are bred for their fur, are becoming rather common in some parts of the United States and Canada. [See Fig. 6–17.] The fur of the seal, too, is valuable. In fact,

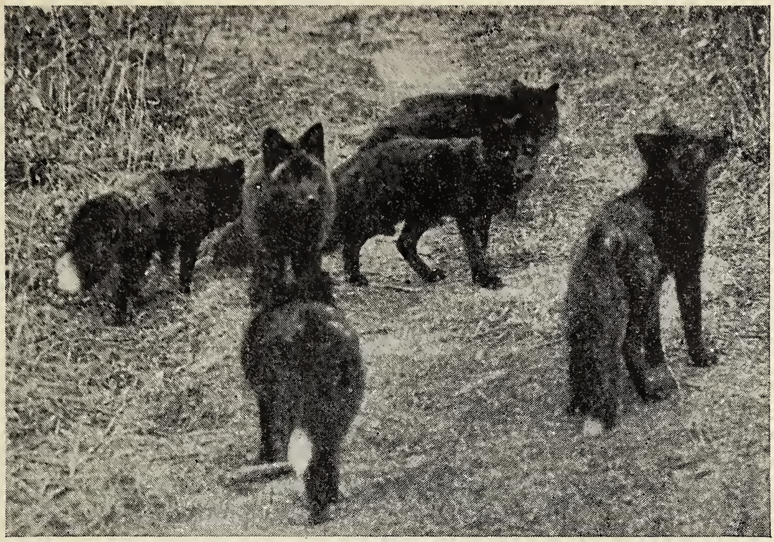


FIG. 6–17. The young silver foxes shown in this picture are growing up at a fox farm on Prince Edward Island, one of the Maritime Provinces of Canada. (*Ewing Galloway*)

it is so valuable that international laws have been passed to protect the seals in the Alaskan waters and prevent their complete extermination.

148. Why is fur so valuable? The value of a fur depends upon its thickness and its ability to resist wear. Squirrel and rabbit fur are both soft and thick, but the hair wears off rather quickly. The fur of the skunk is hard and wiry; hence it makes a durable fur. The cost of a particular fur depends not only upon the quality of the fur and its durability, but also to a great extent upon the scarcity or the abundance of the supply.

Fur garments retain warmth in winter, because so much dead air is included in the spaces within the fur, and air that is not moving is a very poor conductor of heat. It does not permit the heat from the body of the wearer to escape to the colder air outside. Fur-lined mittens and coats are warmer in windy weather than those which have the fur on the

outside, because the wind cannot blow the fur and disturb the dead air spaces. Of course a fur garment is more beautiful when the fur is on the outside.

*149. **How is leather made?** The skins of large animals, such as the cow, the steer, or the horse, are known as *hides.* The skin of a young animal, such as a calf, is known as a *kip.* The skin of a small animal, such as a pig, sheep, or goat, is known as a *skin* or *pelt.* [See Fig. 6–18.] When the skin of a fur-bearing animal is removed from the animal, the skin must be treated with certain chemicals to prevent its decay and to change the hide into leather.

In making leather, the process used depends upon the thickness of the hide, and upon the softness of the leather that is desired. The hides are first soaked in fresh water to remove the salt that was added to preserve them during shipment and storage. Any particles of flesh which adhere to the hide are removed. Then the hide is soaked in some chemical which will cause the hide to swell, or to become *plump.*

FIG. 6–18. How fast can a kangaroo run? (*Courtesy Australian News and Information Bureau*)

The hair, too, must be removed from the hide or skin. It may be loosened and partially removed by the use of sodium sulfide or caustic lime. When the hair becomes loose, it is removed by machinery. The hair is dried and used for making felt, for filling mattresses; or for mixing with mortar to be used in plastering.

The skin is then *bated* by being soaked in a solution which neutralizes the lime, and reduces the swollen skin or hide to its normal size. After the bating process is finished, the skin is ready to be *tanned*, or to be changed into leather by the *tanning* process.

Hides decompose rather quickly, but leather resists decay. In changing hides into leather, a chemical called *tannin* is used. Tannin comes from the bark of trees. Bark especially rich in tannin is called *tanbark*. Hemlock and oak bark are examples of bark rich in tannin. The process of producing leather from hides is called *tanning*. Other chemicals, such as chromic acid, formaldehyde (fôr·măl′dē·hīd), and others, have also been used in the tanning process.

To keep leather from becoming hard when it dries, the tanned skin is put into a *tumbling machine*, which revolves and shakes it up in an *emulsion* of oil and water. The oil soaks into the leather and keeps it soft and pliable. It helps, too, to make the leather somewhat waterproof. Dyes may be introduced into leather by the use of a similar method, by soaking the leather in the dyes.

150. Why is leather important? Look through your home and see how many articles you can find which are made of leather. You will find that the footwear for the entire family is largely made from leather. Thick hides are split into many different layers for use in making the upper parts of shoes. The question sometimes asked, "How many skins has a cow?" is not an idle one. Patent leather is produced from split skins, which are treated with several coats of linseed oil mixed with lampblack, thoroughly dried, and then varnished.

You may find, too, some leather jackets or breeches, although such leather garments are more largely worn in some European countries than in the United States. Possibly the football player has a leather helmet, and he may be kicking a football made of pigskin. Baseballs are covered with horsehide. You may find in your library some handsome books which are bound in leather. It is possible, too, that your luggage, suitcases, and trunks may be made of leather, or leather bound. Leather cushions are common, and so are leather coverings for chairs and couches.

The United States Government is one of the largest buyers of leather. Try to imagine the large amount of leather needed for boots, belts, puttees, and pistol holders for the infantry. Then, too, the cavalrymen must have leather for saddles, bridles, and harness.

151. What is rubber? The milky sap obtained from certain trees contains water with particles of rubber *suspended* (held in suspension) in it. From this sap of the rubber tree, which is called *latex* (lā′tĕks), the rubber is separated by heating it over a smoky flame, or by the addition of acetic acid to the latex. Rubber prepared in this manner is gummy and sticky in hot weather and becomes brittle in cold weather.

Thanks to a fortunate discovery made by an American, Charles Goodyear, both of the defects of natural rubber can be remedied. Goodyear found that rubber becomes fit for a number of purposes if it is heated with sulfur. The process is known as *vulcanizing.* When rubber has been properly vulcanized, it remains pliable and elastic at ordinary temperatures. It does not become sticky or gummy on hot days, or brittle in cold weather. Hard rubber is produced by using larger quantities of sulfur in vulcanizing.

152. How is rubber used for clothing? It is difficult to class either leather or rubber among the textiles, because they are not spun or woven, but both are used in making clothing. Rubber used for such purposes usually consists of

some woven fabric which is coated with rubber to make it waterproof.

Such rubberized fabrics find use in making aprons for kitchen or laboratory use, for making rubber boots and storm rubbers, and for making raincoats. Gloves made from vulcanized rubber are used for many different purposes.

153. What is asbestos? Some minerals have a fibrous structure. *Asbestos* and *chrysotile* (krĭs′ō·tĭl) are two such minerals. They are found in Italy, Australia, the United States, and Canada, but in normal times Canada and Italy furnish the largest amounts. [See Fig. 6–19.] The asbestos

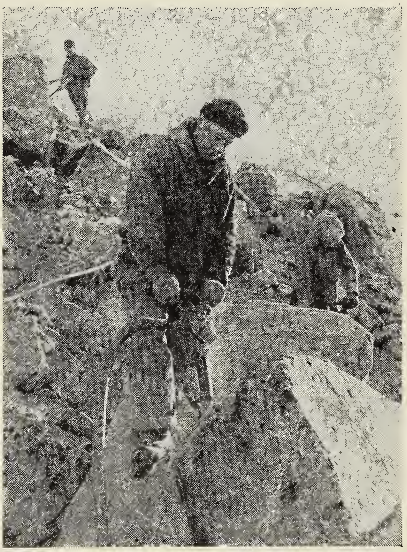


FIG. 6–19. This hillside contains a large quantity of asbestos. The men are drilling holes in the asbestos rock; into these holes will go dynamite to break the rocks into smaller pieces. The cloth which is made from asbestos fibers is almost fireproof. It is said that Charlemagne, who ruled France over a thousand years ago, had an asbestos tablecloth which was cleaned by fire. (*Courtesy Johns-Manville Corp.*)

fibers are long enough to be woven into cloth or twisted into twine. Such fabric is almost fireproof. Hence it is used for making suits for firemen, for making theater fire curtains, for wrapping wires to make insulated cords which can be used for electric flatirons, and in various other ways. Some fibers which are too short to be spun are used with cement in the manufacture of fireproof shingles for roofing.

QUESTIONS

1. What is meant by the saying that was common at one time, "Cotton is king"?
2. Mention three ways in which man is superior to other animals. Can you name one way in which some animals are superior to man?
3. How have man's ideas about clothing himself changed through the past centuries?
4. What is meant by *shoddy?* Explain why it does not wear well.
5. How is mercerized cotton made? What advantages does it have over ordinary cotton fabrics?
6. A tailor gives you a sample of cloth which he says is pure wool. How can you check his statement?
7. Are the seeds of the cotton plant useful? Explain.
8. Can you explain why the retting and scutching of flax is an unpleasant task?
9. Which feels warmer, cotton clothing or linen clothing? Give a reason for your answer.
10. In what countries is flax grown? What countries are known for their fine linen laces?
11. Why is cotton clothing popular in India, and woolen clothing popular in Canada?
12. If your appetite were as ravenous as that of a tiny silkworm, how many tons of food would you eat in a month?
13. For what kinds of work would you need a suit made from asbestos fibers?
14. Why are fur coats so popular with women? Explain why fur coats are likely to be expensive.
15. What are the advantages and the disadvantages in the use of leather for clothing?
16. What is the chief reason for the use of rubber boots or rubber garments? What is the objection to wearing them steadily?
17. From what raw materials is rayon made? Is it correct to call rayon artificial silk?

18. In what ways is rayon superior to silk? In what ways is silk superior to rayon?

19. What are some ways in which a new discovery may change an industry?

Some things for you to do

1. Examine each of the fibers we have studied, using a compound microscope. Make a sketch of each one.

2. Put a sample of mixed cotton and woolen cloth in a dish. Pour upon it enough of a five-per-cent solution of sodium hydroxide to cover it completely. Heat the solution nearly to boiling. What do you observe?

3. Use a piece of the same sample that you used in No. 2. Treat it with warm, concentrated hydrochloric acid. What is the effect? This experiment should be made only under the direction of your teacher.

Think about these!

1. What is the importance of warp and woof in your clothing?
2. How is science used in laundry and dry cleaning?
3. How can you remove stains from your clothing?

Words for this chapter

Warp. The threads extended lengthwise in the loom for weaving.

Woof. The filling threads which cross the warp in weaving.

Bleed. Of a dye, to run when the dyed fabric is laundered.

Fuller's earth. A white or brown powdery substance used by tailors in taking spots out of fabrics.

Aqua (ăk′wȧ) **ammonia.** Ordinary household ammonia; a solution of ammonia gas in water.

CHAPTER 7 ______________ UNIT 3

How Can Clothing Be Kept Clean?

154. How are fabrics made? In the preceding chapter we studied about many fibers which are used in making cloth. Some fabrics are made entirely of cotton; others are made entirely from wool. In some cases, the *warp* may be made from cotton, and the *woof* from wool. Sometimes the back of the fabric may be made from cotton or linen, and the face of the fabric may be made from silk. It is possible to mercerize the cotton to improve its appearance. The appearance of the finished fabric depends, too, upon the tightness with which the thread is twisted and upon the closeness of the weave.

Some fabrics are preshrunk before they are put on the market. It is true, too, that few natural fibers are white in appearance. Nearly all of them have a yellowish color. For that reason, they are usually bleached before they are put on the market. You can see the natural yellow tint of cotton fibers if you examine a piece of unbleached muslin.

Linen fibers, too, have considerable color unless they are carefully bleached. Neither wool nor silk is colorless.

*155. **How is cloth bleached?** In the bleaching of fabrics, two things must be considered. Some chemical must be found which will destroy the natural color of the fibers. The chemical used to destroy the color must not weaken the fibers or destroy them. For these reasons, different chemicals are used with different fibers.

a) *Bleaching cotton.* One of the most effective bleaching agents is *chlorine.* This gas is set free when a dilute acid is added to *bleaching powder,* or *chlorinated lime.* When cotton goods are wet, chlorine destroys the natural yellow color of the cotton fibers and makes them snowy-white. After the bleaching, all traces of chlorine must be removed from the cloth. If this is not done, the chlorine will slowly form hydrochloric acid, in sufficient quantity to weaken the cotton fibers.

b) *Bleaching linen.* Although linen and cotton fibers are so much alike, yet chlorine attacks linen fibers more readily than it does cotton fibers. For that reason, chlorine is not used to bleach linen fibers. In Ireland, for example, the linen is spread out on the grass where the light of the sun helps to bleach it. It is believed, too, that the *ozone* which is dissolved in the dew aids in the bleaching process.

c) *Bleaching wool and silk.* Chlorine destroys both woolen and silk fibers. Hence both woolen fabrics and those made of silk must be bleached by the use of some other chemical. *Hydrogen peroxide* is sometimes used. Sometimes the fumes from burning sulfur are used to bleach both wool and silk. Straw, too, can be bleached by this gas, which is called sulfur dioxide, but the bleach is not permanent. No doubt you have found that a new straw hat becomes yellow when worn only a short time in sunlight. It is an interesting fact that cherries, molasses, figs, and other foods are sometimes bleached by means of sulfur dioxide. [See Fig. 7–1.]

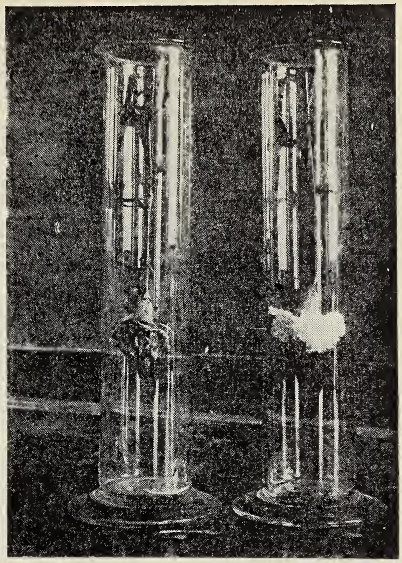


FIG. 7–1. Sulfur dioxide bleaches easily and quickly some colored flowers. Red carnations are bleached white in a short time. Cherries are bleached and then dyed in making maraschino cherries. Straw hats and newspapers, too, are bleached with sulfur dioxide. (*W. R. Bennett*)

156. Are different dyes used for different fabrics? Possibly at some time your mother sent you to the store to match a sample of colored thread, ribbon, or other fabric. You may have found dozens of different colors and shades, and it is possible that no one of them exactly matched your sample. Thousands of different dyes and shades have been made. Some have been obtained from animal sources; some have been made from dyewoods and from berries; the largest number of them have been made by man in the chemical laboratories of the world. Some dyes are suitable for use with silk and wool. Other dyes can be used only for cotton or linen.

In the whole group of dyestuffs there is no such thing as an absolutely *fast* dye. Some dyes are relatively fast when used for cotton and linen, and others are relatively fast when used for silk and wool. Some dyes hold their color well when exposed to sunlight but fade rapidly when washed in soapy water. For example, the dyes used for the flowers in a woman's hat do not fade in sunlight, but it is not advisable to try to launder them. Some other dyes are fast

when laundered, but must be kept out of direct sunlight while they are being dried.

Some dyes *bleed* badly when the fabric is laundered. This may leave the garment streaked, and the dye which bleeds out of the colored garment may stain other clothing which is being laundered at the same time. In the laundry, or in removing spots and stains from colored fabrics, one must be careful to test some of the fibers from the inside seams of the garment first, in order to see whether the dye will be affected by the laundering process or by the chemical used to remove the spot or stain. If the dye in the fiber does not run or bleed, then the entire garment may be laundered, or as much of the garment may be treated with the chemical as is necessary to remove the spots and stains.

*157. **What is dirt?** When we speak of something as being *dirty*, we mean that it has been soiled by earth, dust, mud, or other foreign matter which clings to it and spoils its appearance. Dirt may be considered to be foreign matter in the wrong place. Our hands are moist from perspiration, and our skin is somewhat oily. For both these reasons, dirt sticks to our skin. In order to remove such dirt, it is better to use warm water than cold water. Soap added to the water helps to remove the film of oil which makes the dirt stick to our hands or to our skin.

Our dinner dishes are not really dirty after use, but particles of foreign matter from our food stick to the dishes. If some of our food is greasy, the grease sticks to the dishes, and particles of food stick to the grease. In washing greasy dishes, the water must be hot enough to melt the semi-solid particles of grease and form oil drops which can be washed away. Enough soap or scouring powder must be added to the dishwater to form an emulsion with the oil particles and the hot water.

In the laundry, the principle of removing dirt from fabrics is similar. Garments in contact with the skin soil easily when they are moist from perspiration. They may be slightly

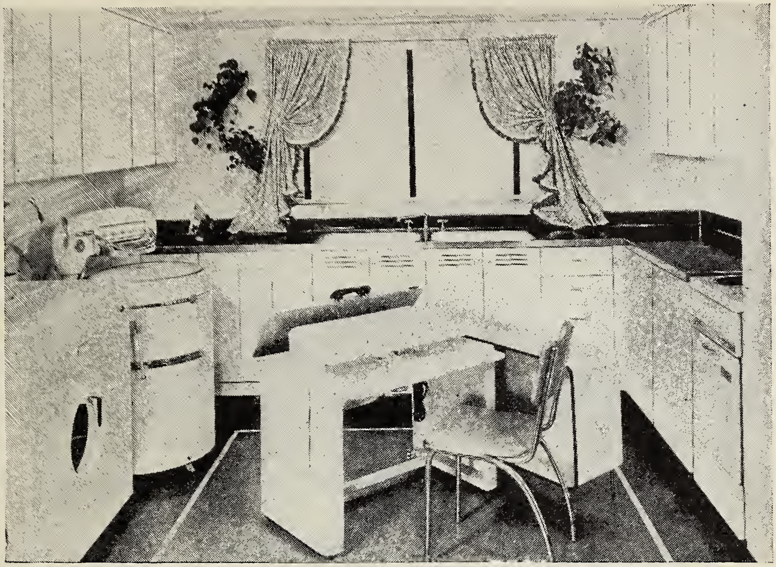


FIG. 7–2. Modern laundry equipment for the home is now attractive enough to be kept in and used in the equally modern kitchen. It is easy to be scientific about washing clothing with such equipment. (*Courtesy General Electric*)

oily, too. A careful laundress learns to be rather scientific in the process of washing clothes. [See Fig. 7–2.]

158. How does the scientific laundress prepare for laundry work? You may be interested to watch the laundress to see whether she proceeds in a skillful and orderly manner.

a) She may remove any bad spots or stains, in table linen for example, by using one of the methods given in the latter part of this chapter. Such a procedure lessens the amount of time needed for rubbing the fabric during the washing, and thus lengthens the life of the fabric.

b) If ripped and torn places are sewed or mended, and loose buttons sewed on firmly, before the garments are washed, several things will be avoided. The holes or rents will not be made larger by the laundering process, the buttons will not be lost, and the garments will not become soiled or wrinkled during the mending process.

c) The careful laundress will separate the colored fabrics from the white clothing, the table linen, and the bedding. The colored pieces should be washed separately to avoid staining the white pieces if any of the dyes in the colored goods should bleed.

d) The white pieces which are only slightly soiled, such as table napkins, may be washed first to avoid excessive rubbing, or agitation in the washing machine. Towels, for example, are likely to require much more labor during their laundering than some other pieces.

e) White clothes, and colored ones, too, can be washed with much less effort, if they have been soaked in warm water overnight before being laundered. A little soap added to the water, or rubbed on the clothes, is also desirable in the soaking process.

f) If hard water is to be used for laundry work, it may be softened by the addition of a little washing soda. A scientific laundress soon learns how much washing soda to use, and she soon learns how much soap is required to form the right amount of suds. Much soap is wasted in the laundry.

g) The laundress may use a thermometer to measure the temperature of the water. Water that has a temperature of from 130° F. to 150° F. works well for the suds used in washing white goods. Water which has a lower temperature should be used with colored fabrics. Woolen and silk fabrics should never be washed in water that is much warmer than blood heat.

159. What is the laundering process? There are several main steps in the laundering process. We may describe each one as follows:

a) *The washing.* After the clothes have been treated as suggested in the preceding paragraphs, they are placed in clean, soft water of the proper temperature. Enough soap is added to form moderately heavy suds. If an old-fashioned washboard is used, the clothes are rubbed on a corrugated,

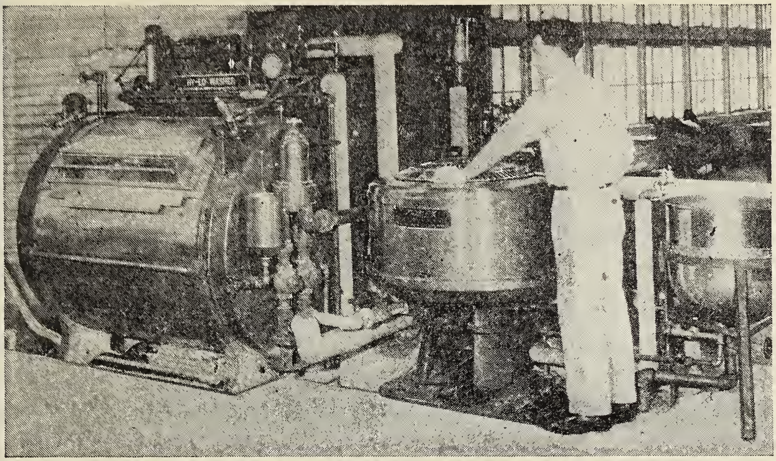


FIG. 7–3. In a modern laundry, clothes are washed in pure soft water. The washers have an automatic control. Six sudsings and seven rinsings are standard practice. The equipment shown here is for washing blankets. (*Courtesy Knickerbocker Laundry*)

or ridged, metal board, or on a glass-faced board. An electric washing machine may be used to agitate the clothes to loosen and remove the dirt. Several types of washing machines are found on the market. They differ mainly in the method used to keep the clothes in motion. Such motion may be accomplished by stirring, by the use of a plunger, or by the use of suction discs. [See Fig. 7–3.]

b) *The rinsing.* In order to remove the dirty water and the curds of soap from the clothes, it is necessary to rinse the washed fabrics thoroughly with water of about the same temperature as the water used for washing. If the clothes are rinsed a second time, slightly cooler water may be used. If the soap is not all removed by rinsing, it may react with the bluing and form rust spots on the clothing. This is likely to happen when the bluing used is a compound of iron.

c) *The bluing.* White goods which have been laundered a number of times acquire a yellowish color. No amount of washing or rinsing will remove that color, and home bleaching is not satisfactory. The colors blue and yellow are *com-*

plementary colors. That means that blue light combines with yellow light to produce white light. If we dissolve a little bluing in some water and then rinse the white wash in such water, the blue neutralizes the yellow color and gives the fabrics a white color. If too much bluing is used, the clothes will have a blue tint.

d) *The starching.* When starch is heated with water, it forms a paste. If white goods are to be starched, they may be dipped into a hot starch paste and stirred until the fibers are evenly coated with starch.

If cold starch is used, it is suspended in the water, and more care must be used to see that the fabric has been thoroughly stirred in the starch suspension. The heat of the flatiron changes cold starch into a solid when the ironing is done, thus stiffening, or starching, the fabric. [See Fig. 7–4.]

The starch paste should be carefully made so that it contains no lumps to which the iron will stick when the ironing is being done.

Clothes that are starched do not wrinkle easily, and they

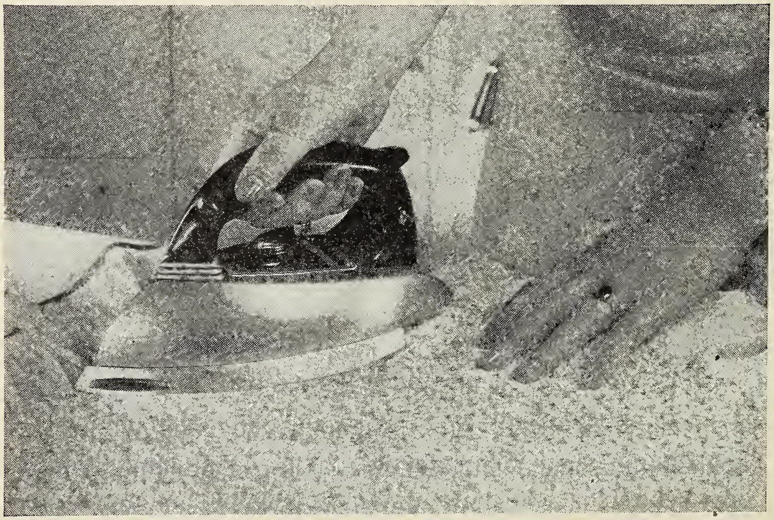
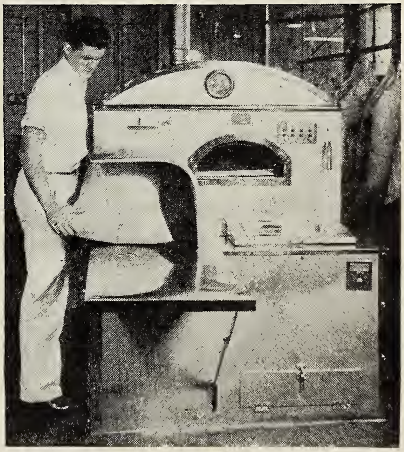


Fig. 7–4. The modern electric iron has made ironing day much easier. (*Courtesy General Electric*)

keep clean longer than unstarched clothes. Muslin, for example, is usually starched by the manufacturer before it is put on the market. Then it does not soil so easily when it is on display in a store. The starch also makes the fabric appear heavier than it really is. A shopper should rub one corner of a piece of muslin or linen to free it from starch before making a purchase. Then he can estimate the weight of the goods more accurately.

160. What is dry cleaning? Many delicate fabrics are injured by water. Sometimes spots which cannot be dissolved in water can be removed by the use of some other solvent. Several different liquids are used in so-called *dry cleaning.* They dissolve grease spots and various other stains, and they evaporate rapidly. They are not so likely to cause the shrinkage of textiles that water often causes. [See Fig. 7–5.]

FIG. 7–5. It is impossible to clean and sterilize pillows at home as they are done in a modern laundry. The ticking is removed and laundered. The feathers are sterilized by live steam and dried by hot air. Then they are returned to the clean ticking. (*Courtesy Knickerbocker Laundry*)



In any attempt at dry cleaning at home, great care must be used to do the work where there is a good circulation of air. This is necessary for two reasons: (*a*) the vapors and fumes from most of the liquids used for dry cleaning are poisonous or suffocating; (*b*) in nearly all cases, the vapors and fumes from such liquids are flammable. Such liquids

as gasoline, benzene, and ether give off vapors which are suffocating and flammable. Dangerous fires may result from their use. *Carbon tetrachloride* is a very satisfactory substitute for gasoline. It is more expensive, but its vapor does not burn and it is actually useful in extinguishing fires. Since its vapor is suffocating, however, it must be used where there is a good draft of air.

161. How can spots be removed from fabrics? Even careful persons sometimes get spots on their clothing or on the table linen. Such spots are unsightly, and dry cleaning may be rather expensive. Hence we try to remove the spots by home methods. The successful removal of stains depends upon the nature of the spot, upon the kind of fabric, upon the color of the fabric, and upon the selection of the right *solvent*, or liquid for dissolving the spot. It is much more difficult if the substance which caused the spot is unknown.

Many spots can be removed by *physical means.* Mud spots, for example, can generally be removed, after the mud has dried, by brushing and rubbing. Then the spot may be sponged gently with a damp cloth. Cold water poured through the fabric will in some cases remove the stain or spot. In other cases, hot water is better. If grease spots are to be removed, some solvent is used to dissolve the grease, but some method must be used to keep the solvent from spreading. If the solvent spreads and then evaporates, a ring of grease is left, fainter than the original spot, but much larger. Several methods of treating grease may be used.

a) The grease spot may be covered with *fuller's earth.* A little depression may be made in the center of the pile of fuller's earth. When the solvent is poured into this depression, it flows down through the fuller's earth and dissolves the grease, which is then absorbed or sucked up into the earth itself. When it is dry, the earth can then be brushed away. Talcum powder may be used instead of fuller's earth, but it is harder to remove by brushing after the operation is finished.

b) Grease which drips from paraffin candles upon the tablecloth can be largely removed by covering the paraffin spot with a piece of good blotting paper, and passing a hot iron over the paper. When the paraffin is melted by the heat of the iron, it is absorbed by the blotting paper.

c) In a piece of blotting paper one may tear a hole about the size of the grease spot. When the solvent is added, the grease dissolves and is absorbed by the blotting paper.

Some stains can be removed only by the use of some chemical to destroy the stain. For example, an acid stain may sometimes be neutralized by the addition of *aqua ammonia.* Ink stains, too, are usually removed by the action of some chemical which destroys the color. In attempting to remove stains from colored fabrics, one should test a small piece of the cloth with the chemical to see whether it will cause the dye to be removed or to change color. One needs to be particularly careful when trying to remove spots from silk or wool, because the fabrics themselves may be injured by the chemicals.

It is necessary to wash out, as thoroughly as possible, the excess chemical that is used to remove the spots and stains. For example, if oxalic acid in solution is used, the excess must be washed out of the fabric, or the fibers will be weakened. Javelle water must never be used on silk, as it destroys it completely. Turpentine, too, will ruin silk. In several cases, especially when the spots and stains are old, it may be necessary to make repeated applications of the solvent or the chemical.

The table on pages 186 and 187 lists some common kinds of stains and gives methods that are generally satisfactory for their removal from wool, silk, cotton, or linen.

Kind of stain	Wool	Silk	Cotton or Linen
Acids	Dilute ammonia.	Dilute ammonia.	Dilute ammonia.
Alkalis	Weak vinegar.	Weak vinegar.	Weak vinegar.
Blood	On white goods, cold water — if fresh. If dried — soapy water, followed by hydrogen peroxide.	Same as for wool.	Same as for wool. Javelle water may be used on white cotton or linen.
Chocolate, or cocoa	Glycerine. Then water.	Glycerine. Then water.	Glycerine. Then water.
Coffee	Glycerine. Then water.	Glycerine. Then water.	Boiling water, if fresh. If dried, Javelle water.
Fruit juices	Hot (not boiling) water. Then soap in alcohol.	Boiling water.	Boiling water. If white, use Javelle water to remove last traces.
Grass	Alcohol. Then soapy water.	Alcohol. Then soapy water.	Alcohol or ammonia. Then soapy water.
Grease	Carbon tetrachloride. Then follow with soap. suds and ammonia.	Same as for wool.	Same as for wool. Fuller's earth may be used with carbon tetrachloride as a solvent.
Chewing gum	Carbon tetrachloride.	Same as for wool.	Same as for wool.
Ice cream	Water. Then soap and water.	Same as for wool.	Same as for wool.
Ink	If fresh, skimmed milk, then water. If dried, oxalic acid. Then hydrogen peroxide.	Same as for wool.	Same as for wool. If dried, oxalic acid. Then Javelle water, or bleaching powder and tartaric acid.

Kind of stain	Wool	Silk	Cotton or Linen
Iodine	Alcohol or ammonia.	Alcohol or ammonia.	Alcohol or ammonia. Sodium sulfite and water. Hypo and water.
Lipstick	Carbon tetrachloride.	Carbon tetrachloride.	Carbon tetrachloride.
Mildew	Soapsuds. Sunlight.	Same as for wool.	Soapsuds. Javelle water. Sunlight.
Paint	Carbon tetrachloride. Soap and ammonia.	Same as for wool.	Same as for wool. Turpentine may be used. Followed by soap and ammonia.
Plaster, adhesive	Alcohol, or carbon tetrachloride.	Same as for wool.	Same as for wool.
Rust	Oxalic acid. Lemon juice and vinegar.	Same as for wool.	Same as for wool.
Shellac	Alcohol.	Alcohol.	Alcohol.
Scorch	Hydrogen peroxide.	Same as for wool.	Same as for wool.
Tar	Lard and kerosene. Then soap and water. Carbon tetrachloride.	Same as for wool.	Same as for wool. Turpentine.
Tea	Same as for coffee.	Same as for wool.	Same as for wool.
Varnish	Equal parts of alcohol, benzol, and acetone.	Same as for wool.	Same as for wool.
Vaseline	Kerosene, followed by warm soap solution.	Same as for wool.	Same as for wool.

QUESTIONS

1. What is a *fast* dye?

2. Notice rugs that have been exposed to sunlight. What effect does the sunlight have on them?

3. What do we mean by *dirt?* Why does it stick to your skin? Why is it necessary to bathe frequently?

4. What are the various steps in the laundering process?

5. What is meant by the *bleeding* of a dye?

6. Why is bluing used in the laundry for white fabrics?

7. Why is starch used in the laundry?

8. What is meant by the term *dry cleaning?*

9. What are the general steps to be followed in order to remove spots and stains?

10. Why should one use carbon tetrachloride instead of gasoline for removing grease spots?

11. Why should dry cleaning always be done where there is a good draft of air?

SOME THINGS FOR YOU TO DO

1. Take a small square of bleached muslin. Let a drop of candle grease fall upon it. Try by two or three different methods to remove the spot.

2. Place a small square of unbleached muslin in a dish. Cover it with a paste of bleaching powder. Add to it a little dilute hydrochloric acid, about 1 part of acid to 10 parts of water. Let it stand for a few minutes; then remove and rinse. What are the results?

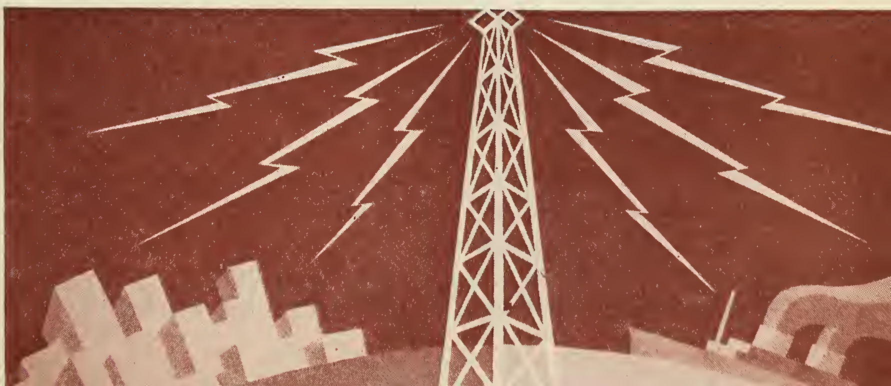
3. If possible, visit a large commercial laundry and compare the methods used there with methods that you have seen used in a private laundry. Tell the class about the visit.

We Use Sound Energy for Communication

WHEN you take a walk, do you find yourself on a street full of the sound of automobile horns and motors running? Or do you walk in the woods where you hear leaves rustling and perhaps a squirrel scolding you? When the rain falls, what noise does it make on your roof? Have you ever waked up to hear a snow shovel scraping a sidewalk?

Do you ever wonder how the sounds that you hear reach your ears? Did you know that sound, like heat, is a form of energy?

In Unit 4 you will find out something about sound energy: what causes sound waves, how they travel to the ear, and how the ear acts as a receiver. You will learn why some sounds are shrill, while others have a low pitch. Perhaps you will form some satisfactory idea of what music is. You will discover how man has made sound energy serve him in communication, and how he has invented the phonograph



and other machines for reproducing sound. And you will be aware constantly of the complex structure of the human ear which makes sound possible.

Think about these!

1. How are sound waves produced? How do they get to your ear?
2. Why are you able to recognize voices, even over the telephone?
3. Phonograph records have been called "canned music." Can you explain why?
4. Do you think that an echo is an amusing occurrence, a nuisance, or something that can be made useful?

Words for this chapter

Vibrate. To move to and fro.

Radio-frequency. Waves which vibrate too rapidly to affect the human ear.

Medium, *plural* **media** (mē′dĭ·*ȧ*). That which lies between things, or in the middle; a substance through which a force acts or an effect is obtained.

Eustachian (ū̇·stā′kĭ·*ă*n) **Tube.** The tube which connects the middle ear with the throat.

Acoustic (*ȧ*·koos′tĭk). Pertaining to the science of sounds.

Overtones. Notes whose pitch is an octave or more higher than that of a given tone.

Fundamental note. The lowest note of a chord; the basic tone.

Larynx (lăr′ĭngks). That organ in the throat by which the voice is produced.

Stylus. A sharp-pointed needle used for engraving.

Condensite (kŏn·dĕn′sīt). An artificial plastic made from carbolic acid and formaldehyde.

Amplify. To increase; to augment; to intensify.

Diaphragm. As used here, a vibrating disc, or membrane.

CHAPTER 8 ______________ UNIT 4

How Does Man Produce and Control Sound?

162. What is the source of sound waves? Possibly some of you may have read that fantastic story by Joseph Addison called "Frozen Words." The story in brief is as follows: On an Arctic expedition, the weather grew so cold that words froze as soon as uttered. The members of the party could be seen talking, but no sounds came. When the weather moderated, there was a confusion of sounds when the frozen words thawed out again. Possibly it rivaled the confusion at the building of the Tower of Babel, as mentioned in the Bible. Man has learned how to preserve speech, but not by refrigeration. But we may well pause to ask, "What is the source of sound, how does it reach our ears, and how do we hear it?"

Let us clamp one end of a thin strip of steel in a vise, and strike the other end a sharp blow. The steel will *vibrate* to and fro and give out sound waves. The vibrations are too rapid for the eye to see them, but we may perform a simple

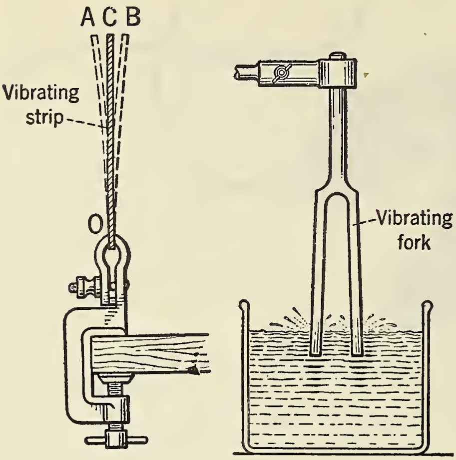


FIG. 8–1. On the left, one end of a metal strip has been clamped in a vise at zero. The free end has been struck and vibrations set up from A to B; the free end will soon come to rest at C. Perhaps this movement cannot be seen. On the right, one of the prongs of a tuning fork has been struck, and the prongs dipped in water; this makes the vibrations visible.

experiment to detect them. We strike one of the prongs of a tuning fork a sharp blow, and then dip the prongs into a glass of water. [See Fig. 8–1.] The water is thrown about by the vibrating fork. If we strike the fork a second time, and hold it near one ear, we hear a musical note that is being produced by the vibrating fork.

Many experiments can be performed to prove that sound always has its origin in some vibrating matter. It does not make any difference how the vibrations are produced. For example, in some musical instruments a string is plucked to make it vibrate. In other cases the string is struck, and in still others it is bowed. Sound does not always have its origin in a vibrating solid, either. If one blows across the edge of the opening of a flute, he produces sound by throwing a column of air into vibration. [See Fig. 8–2.]

163. Do all vibrations produce sound waves? If we wave a stick back and forth in the air at the rate of from 8 to 10 times per second, it does not produce sound waves. If we make it vibrate faster, it begins to produce sound waves. Some persons hear sound when the stick is vibrating 16 times per second. That seems to be the lowest vibration rate which will produce sound. The ears of some other persons are not

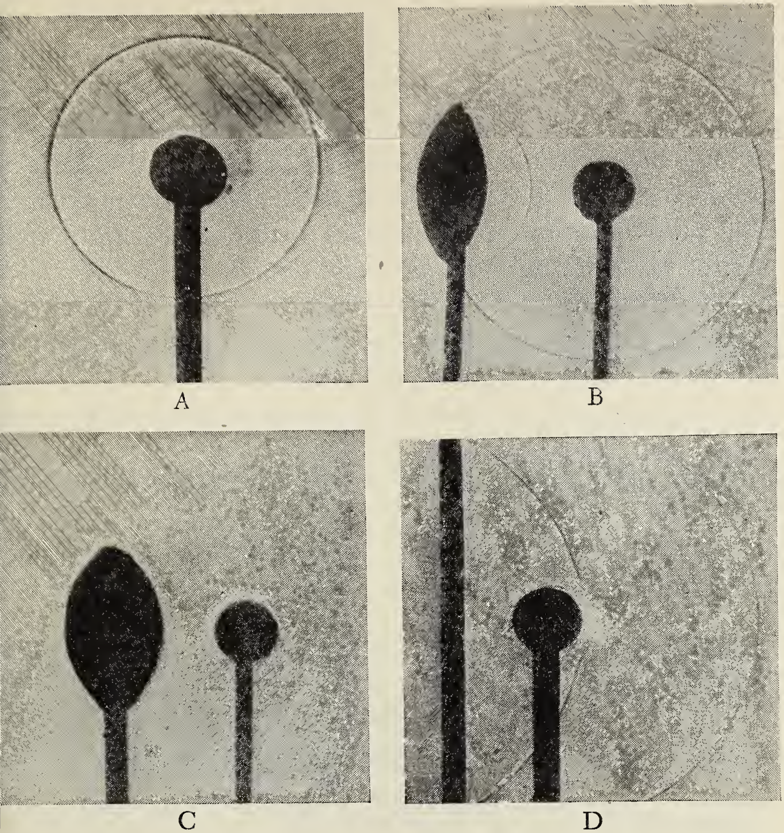


Fig. 8–2. Four photographs of sound waves. A shows a simple sound wave going out from its source. In B a sound wave is reflected from a convex surface, and in C those same waves, a fraction of a second later, are shown. In D we can see a simple sound wave and a sound wave reflected from a flat surface. (*Courtesy Professor A. L. Foley*)

sensitive to vibrations that occur 16 times per second, and they do not hear any sound unless the number of vibrations per second reaches about 27, which is about the number produced when we strike the key for the lowest note on a piano.

Scientists have discovered by experiment that most human ears are not sensitive to those waves produced when the vibrations are more rapid than 20,000 per second. Thus

some insects are known to produce sound waves which we cannot hear. Bats can produce super-shrill sounds, inaudible to us, having 50,000 vibrations per second. The human voice, in general, produces sound waves ranging between 90 and 800 vibrations a second. Musical instruments can produce a range of from 30 to 40,000 sound waves a second. The term *radio-frequency* applies to those vibrations that are too rapid for any human ear to detect.

164. How do sound waves reach the ear? If one drops a pebble into the center of a pool or pond, a water wave is produced. Such a wave spreads out in increasing circles. The diameters of the circles increase, but the waves grow fainter and fainter until they die out.

When one speaks in the open air, his vocal cords start a sound wave which spreads out like the water wave set up by the pebble. The sound wave spreads out in all directions, but it grows fainter and fainter. [See Fig. 8–3.]

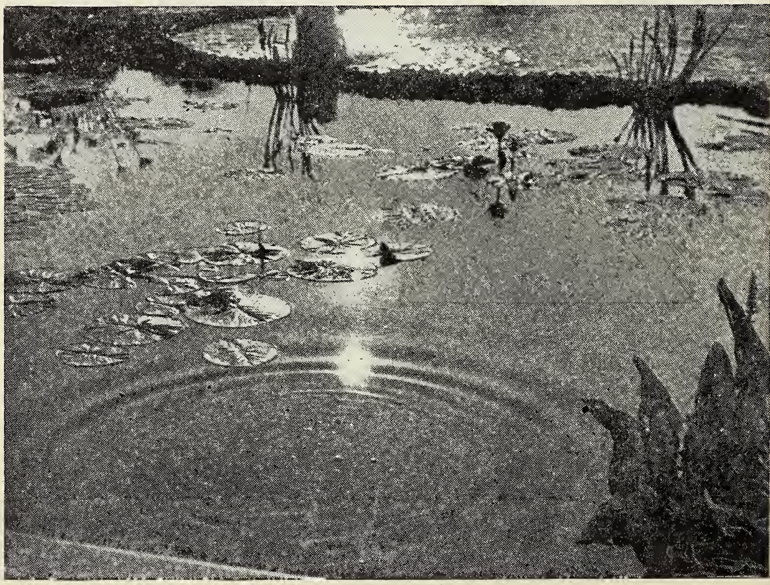


FIG. 8–3. Sound waves spread out very much like water waves set up by a thrown stone or a jumping frog. (*Philip D. Gendreau*)

Most of the sound waves that we hear come to us by traveling through the air. They must have some medium through which they can travel. On the top of a high mountain where the air is less dense, one must speak more loudly in order to be heard. It has been proved that sound waves do not travel through a vacuum at all. An alarm clock in a jar from which the air has been removed cannot be heard.

While air is the most common *medium* for the transmission of sound, liquids and solids are better media. If one holds his head under water while a person several feet away claps two stones together under water, the sound is so intense that it is almost painful. The sound wave originates in the water and travels through the water. An explosion beneath the surface of the water produces such intense waves that fish some distance away are stunned by the force. Fish undoubtedly hear very well, if the vibrations originate in the water itself or in the bordering land. It is doubtful whether fish under the water hear ordinary conversation between two persons on the bank of the stream or in a boat.

If you tap on the steampipe in the basement, the sound waves travel through the iron pipe to all parts of the house. The solid iron is an excellent transmitter of sound waves. If you hold your ear near one rail of a railroad track, you may hear a train a long distance away. Michael Pupin (pū·pēn′) tells how Serbian shepherd boys attracted each other's attention by striking on the ground; the solid earth transmitted the sound much better than the air above it would have transmitted it. Edison was very hard of hearing. He listened to a phonograph by resting his head against the cabinet. The sounds from the cabinet traveled through the bones of his head to the ear. The munching of dry toast sounds very loud to the person eating, because the sound waves travel through the jawbone to the ear.

165. Is it possible to have sound insulators? You know that a rug on the floor of a room deadens the sound. You know, too, that you walk more quietly on rubber-soled shoes.

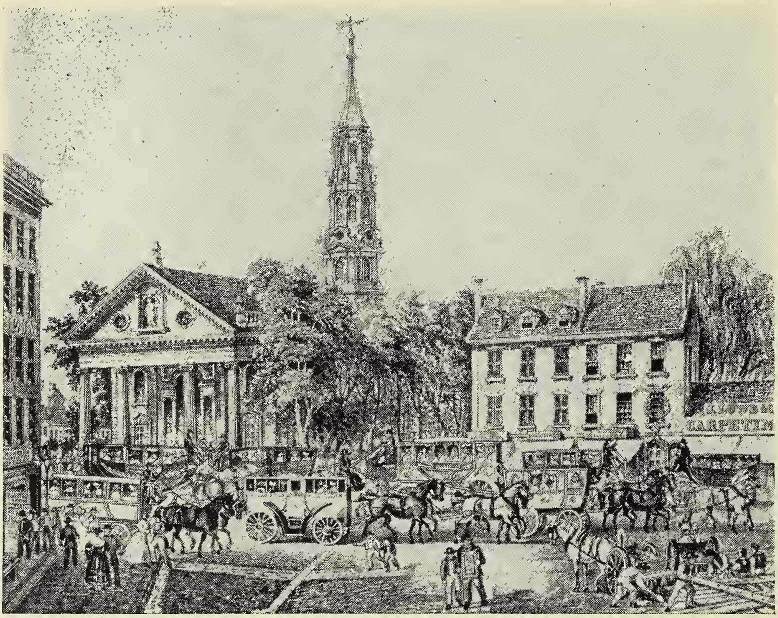


FIG. 8–4. Broadway, in New York City, about 110 years ago. Even in the "good old days," busy streets were likely to be noisy. How does the noise of today differ from the noise in the days of the stagecoach? (*Courtesy of The New York Historical Society*)

In fact, the word *gumshoe* has become a commonplace adjective for describing detective work. Cork floors are used in some churches. Rubber-tired automobiles glide over the pavements with little noise compared to the rumble and clatter of motor trucks, trolley cars, or horse-drawn wagons. [See Fig. 8–4.] Sawdust, straw, felt, Celotex (sĕl′ō·tĕks), and plaster board are often used to deaden sound, or to serve as sound insulators.

166. How fast do sound waves travel? (*a*) *In air.* We see a flash of lightning, but it may be several seconds before we hear the thunder. We see the "steam" coming from a distant locomotive a few seconds before we hear the whistle. From such observations, it becomes evident that sound waves travel more slowly than do light waves. We have

learned that light travels at the very great speed of more than 186,000 miles per second. For that reason, we may consider that light coming from a short distance reaches us instantly, or that the time needed for light to travel a short distance is too small to measure and that it may be neglected.

The speed at which sound travels through air was measured by setting up two cannon on hills several miles apart. There was a group of observers on each hill. When one cannon was fired, that group on the distant hill noted the flash of light, and then counted the number of seconds before the sound reached them. Then the cannon on the other hill was fired, and the time needed for the sound to reach the group on the opposite hill was measured by them. Several trials were taken to find the average time needed for the sound to travel from hill to hill. Errors due to wind were corrected by taking the time required for the sound to travel in each direction, and then getting the average. The distance between the two cannon was carefully measured.

The results of such an experiment and of other types show that *sound waves travel in air at a speed of 1090 feet per second, if the temperature is 0° C., or 32° F.* An increase of one degree Centigrade in the temperature causes an increase of two feet per second in the velocity at which sound travels in air. Hence, in a room of ordinary temperature, 20° C., or 68° F., sound waves travel at a velocity of 1130 feet per second.

b) *In water.* An interesting experiment was performed at Lake Geneva, Switzerland, a number of years ago. Sounds were produced under water, and the time required for them to travel a measured distance was carefully noted. As a result of the experiments, it is found that *sound travels in water about four times as fast as it does in air.*

c) *In solids.* Some other methods have been used, too, to find the velocity of sound in solids. It varies a great deal with the solid used. In such solids as glass and steel, sound travels about *sixteen times* as fast as it does in air.

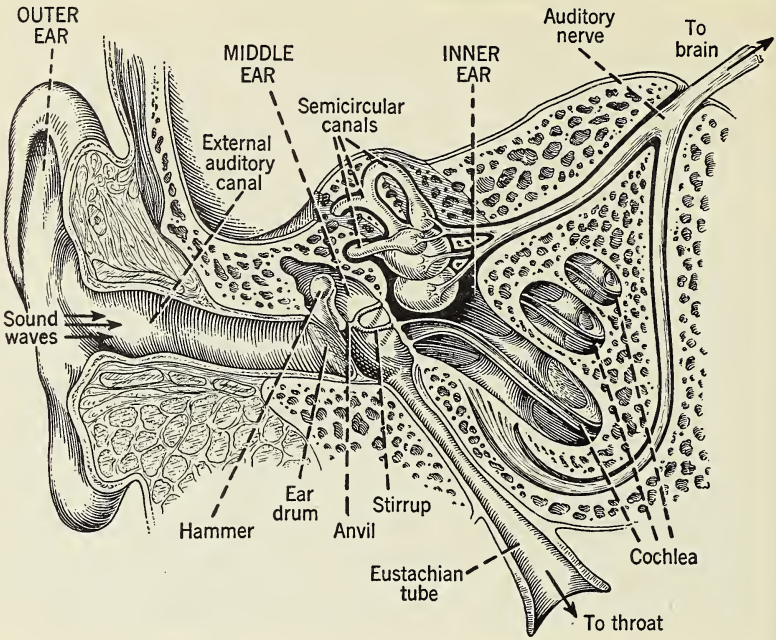


FIG. 8–5. The three parts of the human ear.

167. How does the ear act as a receiver for sound waves? In a simple telephone system we have a transmitter, or device for sending the message; wires to transmit the electric waves; and a receiver. In order for us to hear, we must have a vibrating body to produce the sound waves, some medium (usually air) to transmit those waves, and the ear which serves as a receiver.

The human ear consists of three parts: the *outer ear,* the *middle ear,* and the *inner ear.* [See Fig. 8–5.]

a) *The outer ear.* The outer, visible part of the ear consists mainly of a thin piece of cartilage covered with skin. It is irregular in shape, and has a number of grooves, all leading toward the middle ear. The grooves of the outer ear collect sound waves and lead them to the eardrum.

b) *The middle ear.* This part of each ear is about the size of a small cherry. It is connected with the throat by means

of a small tube called the *Eustachian* tube. If this tube is kept open, the air pressure will be the same on both sides of the drum which separates the external ear from the middle ear. The eardrum consists of a thin, elastic membrane, which can receive the vibrations, and pass them on. Three tiny bones in the middle ear receive the vibrations from the eardrum and send them on to the inner ear. Here we have an example of solids in the ear being used to transmit sound waves.

c) *The inner ear.* Let us refer to Figure 8–5. We see that the inner ear consists of three different parts. First, there is a vestibule which connects the other two parts of the inner ear. It is filled with liquid. Second, there are the semicircular canals of the inner ear. They are three in number, all set at angles to one another. They seem to have something to do with keeping the body balanced. If they are injured, one cannot perform complicated muscular motions well. A person who wishes to become an airplane pilot is given tests to see how well his semicircular canals function. Third, there is the *cochlea* (kŏk′lē·*ȧ*), so named because it is shaped like a snail's shell. The word *cochlea* means *snail* in Latin. This portion of the ear is filled with fluid too. In the cochlea the delicate hairs connected with the nerves of hearing are spread out something like the strings of a harp. The sound waves, collected by the outer ear, and transmitted along the bones of the middle ear and through the fluids of the vestibule and the cochlea, fall upon these hairs. The sound waves move these hairs, and impulses are set up in the nerves and carried to the brain by the auditory nerve. In some strange way, this impulse is translated by the brain and the mind to cause the sensation which we call *sound.* The details of what happens in the inner ear when sound waves enter will be taken up in Chapter 16.

168. How are echoes produced? We all know that an echo comes back to us when we stand some distance from a wall, a cliff, or a forest, and utter a loud shout.

Just as a rubber ball which is thrown against a wall rebounds and returns again, so a sound wave which we produce is turned back from a distant cliff and returns to us again. We hear the sound when we utter it, and we hear it a second time when the sound wave is reflected from the distant cliff. [See Fig. 8–6.] Such a *repetition* of sound is an echo.

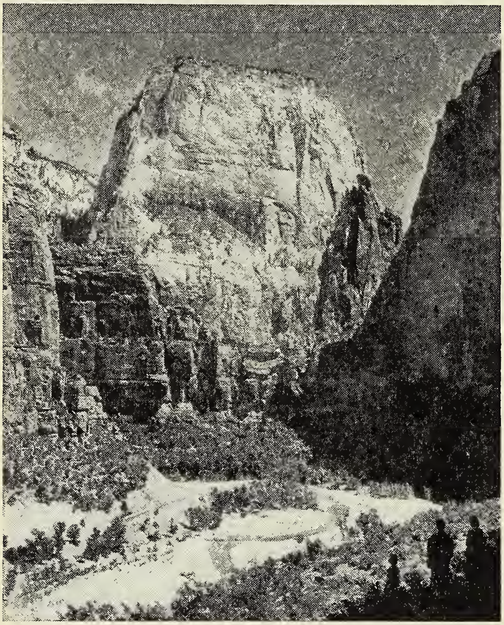


FIG. 8–6. In many parts of the West there are formations, such as the one pictured here, which reflect sound and thus create echoes. The word *echo* comes from a character in Greek mythology; you may enjoy the story of the nymph, Echo. Can you understand why echoes have been a part of early superstitious tales? (*Union Pacific Railroad Photo*)

Sometimes a sound wave may be reflected back and forth between two parallel walls in such a manner that a listener who stands between the walls hears the sound repeated several times. A remarkable case of this kind occurred in one of the cities of Indiana. The word *knickerbocker,* when uttered loudly at a certain spot between the walls of two buildings, was repeated twenty times before the echo finally died away entirely. The rolling of thunder is a good example of the repetition of echoes, as the sound wave is reflected from cloud to cloud, causing echoes and re-echoes.

169. Can echoes be made useful? We know how fast sounds travels in air and in water. It has been shown by experiment that the reflected sound wave that causes an echo travels at the same speed as the direct sound wave. Suppose one counts two seconds between the time that a pistol is fired and the time that he hears the echo returned from a distant cliff. He can calculate the distance of the cliff, because it takes one second for the sound to reach the cliff, and one second for the sound wave to return. Suppose that the temperature is 68° F., and that the velocity of sound is 1130 feet per second. Then the cliff was just 1130 feet distant from the one firing the pistol. A vessel in a fog may sound the fog horn, and count the number of seconds before the echo returns from the shore, a rocky island, or an iceberg. Echoes are used in such manner to find distances from danger spots, especially during a fog.

It is possible, too, to send a sound signal underneath the water and listen for the return of the echo. The captain of a vessel does this if he wishes to learn the distance from the vessel to the shore. It is possible, too, to find the depth of the water by sending a signal downward, and measuring the time required before the signal is echoed from the bottom. This method of measuring the depth of water is now in extensive use.

170. How can echoes be a nuisance? It is an interesting fact that we continue to hear a sound for about one-tenth of a second after the sound wave has faded out. The sense of sound persists in the brain for that length of time after the nerves of the ear cease to be stimulated.

Suppose we have a school auditorium in which the rear wall is just 56 feet from the speaker's platform. If the velocity of sound on a given day is 1120 feet per second, then it will take a sound wave exactly one-tenth of a second to travel the 112 feet from the speaker to the wall and back again. Just as the sound from one word or syllable uttered by the speaker is fading out in your mind, the echo will come

back and confuse you. It is possible in such a case to hear the speaker, but you cannot understand what he is saying. The original sound waves become scrambled with the returning echo. The echoes are most troublesome. We say that such an auditorium has poor *acoustic* properties. When the room is full of people, the sound wave may be broken up, and the echoes will then prove less troublesome.

When we say that the acoustic properties of a room are good, we mean that the room is free from troublesome echoes when someone is speaking. Draperies are sometimes suspended in a room to break up sound waves and prevent echoes. Much attention should be given by the architect who plans an auditorium for school, church, or theater to see that troublesome echoes are avoided and that the room will have good acoustic properties. [See Fig. 8–7.]

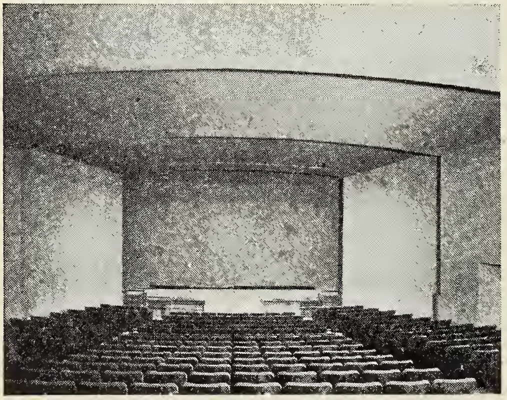


FIG. 8–7. Have you ever been in an auditorium where echoes made it difficult for you to hear because they disturbed the sound waves? This auditorium has been lined with asbestos, which absorbs much of the sound, eliminating echoes. (*Courtesy Keasbey & Mattison Co.*)

171. How do sound waves differ? A bulldog growls in a deep bass voice, but the chirp of a cricket has a shrill note. Either a deep note or a shrill note may be loud, and either one may be so soft that it is barely audible. A tenor singer may sing as true to pitch as a Caruso, but his voice may not be so pleasing. We say that the quality is not so good. We pay more to hear some persons sing than to hear others. It is possible for sound waves to differ in three ways: *loudness*, *pitch*, and *quality*.

172. Upon what factors does the loudness of a sound depend? A heavy stone which is thrown into the water causes more intense waves than a small pebble does. In a similar manner, the heavy string of a bass viol throws more air into vibration than a violin string does, and it produces a more *intense* sound. A cannon produces a more intense sound when fired than a small toy pistol does.

The vigor with which a violin string is bowed or plucked affects the intensity of the sound wave which it produces. We may tap a piano key gently and produce a soft sound, or we may strike it forcibly and set up an intense sound.

The farther distant one is from a vibrating body, the fainter the sound becomes. In fact, a church bell sounds four times as loud to a person one-half mile distant as it does to a person one mile away.

As the air grows less and less dense, sound waves transmitted by it decrease in loudness.

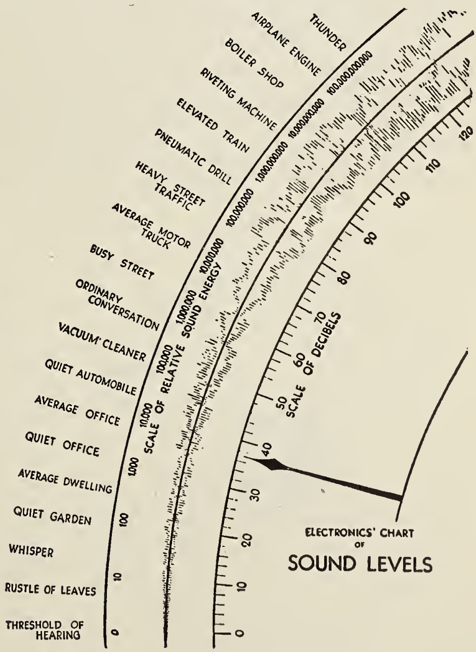


FIG. 8–8. This chart shows the approximate number of decibels in some rather common sounds. Using this chart as a guide, see if you can make a chart of the decibels in the sounds you hear on an average morning – when you get out of bed in the morning, while you are eating breakfast, when you are on your way to school, or when you are in the schoolroom. You will be surprised at the number of decibels in sounds such as a frog's croaking or a person's screaming. (*Courtesy "Electronics"*)

173. How is loudness of sound measured? The unit which is used for measuring loudness is the *bel.* The unit is named in honor of Alexander Graham Bell. The decibel is a smaller unit, which is one-tenth of a bel. A decibel meter is used to measure in decibels the loudness of sounds around the home or the factory, or on streets. [See Fig. 8–8.]

A whisper ranges from 10 to 20 decibels; a rather quiet office, from 20 to 40 decibels; a modern automobile, from 40 to 50 decibels; ordinary conversation, about 60 decibels; motor trucks and heavy street traffic, 70 to 80 decibels; elevated trains, 90 to 100 decibels; thunder, about 110 decibels; sounds ranging from 120 to 130 decibels are almost painful. Of course, there is considerable variation in the loudness of the different sounds mentioned in this list.

174. Upon what factors does pitch depend? If we permit a phonograph to run down while a record is being played, we find that the pitch grows lower and lower as the turntable slows down. The needle vibrates more slowly, and the pitch is lowered. The siren disc shown in Figure 8–9 contains varying numbers of holes in the different rows. As one blows through the holes of the disc, the air that passes through the opening is thrown into vibration. If the disc is rotated rapidly, it produces a note of a certain pitch. Let us

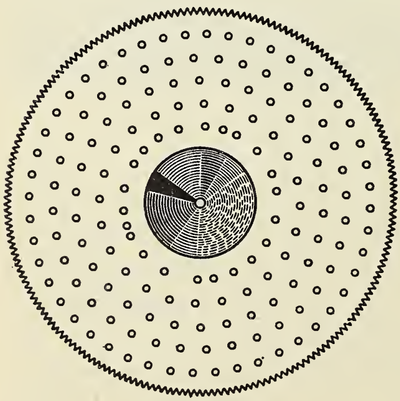


FIG. 8–9. By means of a siren disc, you can learn many interesting things about pitch. For example, to produce the note high C, the vibrations must be twice as fast as to produce the note middle C, one octave lower in pitch. The vocal cords of a woman can usually vibrate faster than can those of a man.

rotate the disc more rapidly and repeat the experiment. We find that a shriller note is produced. It may be shown by experiment, too, that a note of higher pitch is produced when one blows through the row of holes that contains the largest number. Thus we find that *the pitch of a sound depends upon the number of vibrations which reach the ear per second.*

The short, thin, tight strings of a piano yield notes of high pitch, but the long, thick, loose strings of a piano produce the bass notes, or those of low pitch. If we shorten a violin string, or stretch it more tightly, it will vibrate faster than it does when the string is long and loosely stretched. A woman's voice is usually more highly pitched than that of a man. Her vocal cords are usually thinner and shorter.

175. What causes the quality of a sound to vary? The intensity of a sound wave seems to depend upon its size; the pitch depends upon the rapidity with which one sound wave follows another; the quality of a sound seems to depend upon the shape and form of the sound wave, and upon its complexity. The quality of a sound depends upon the *overtones* that are blended with the fundamental note. Some overtones are pleasing to the ear and produce sounds of good quality. Other overtones make the sounds discordant.

176. What is noise? When a pile of dishes clatters upon the floor, a ton of coal slides down a chute, an air drill rips through the pavement, or an automobile horn honks raucously at three o'clock in the morning, the sound is *not pleasing.* Sounds which are displeasing to the ear are spoken of as *noise.* Someone has defined noise as *undesired sound.* That definition is not far wrong.

177. What is music? If noise is displeasing to the ear, then we may expect to find that music will be pleasing. William Congreve wrote: "Music hath charms to soothe the savage breast, to soften rocks, or bend a knotted oak." In music, the sound waves reach the ear in fairly regular succession. Irregular vibrations are generally displeasing and produce

noise. Musical instruments are designed to give regular vibrations. In some cases, however, the ear becomes tired of regular vibrations, if they are too often repeated.

178. How are musical notes produced? In musical instruments, there are many different ways of producing vibrations. We shall mention only a few of them.

a) *In stringed instruments.* In the piano, the violin, the harp, the guitar, the mandolin, and the ukulele, the strings are thrown into vibration by plucking, bowing, or striking the strings. The strings are all stretched over a sounding board which reinforces the sound. [See Fig. 8–10.]

If you look at the strings of a piano, you will find that the bass strings are as large in diameter as a lead pencil and several feet long. They are wound with copper to make them denser, and they are loosely stretched. The longer, looser, denser, and thicker a string, the more slowly it vibrates. Hence the bass strings produce notes of low pitch. The

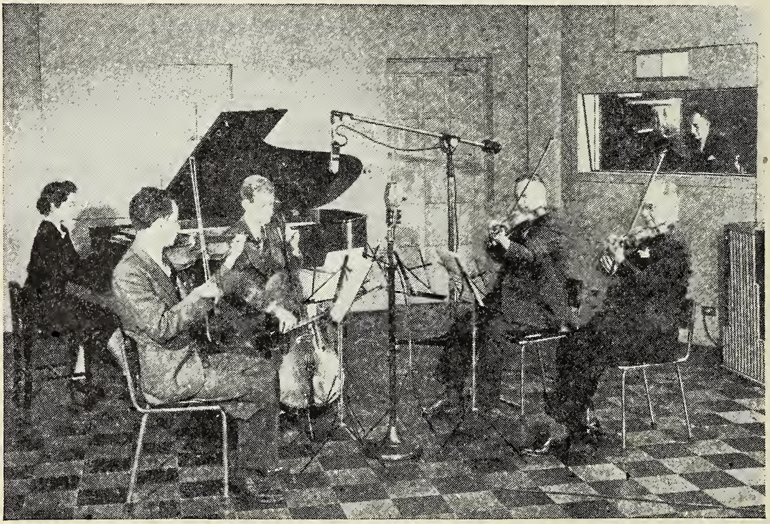


Fig. 8–10. Each of the five musical instruments being used for this radio broadcast produces music by the vibration of strings stretched over a sounding board. (*Courtesy G. Schirmer, Inc., Music Publishers*)

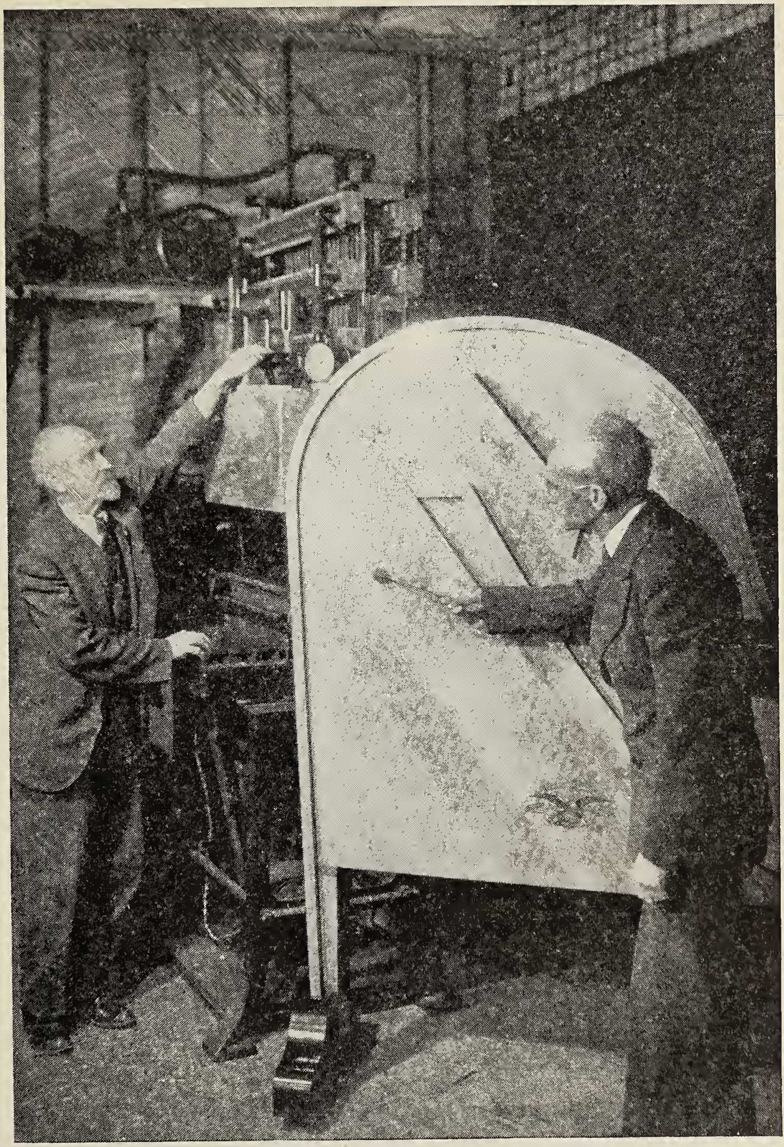


FIG. 8–11. This piano soundboard is being tested for resonance by research workers. Resonance is the enrichment of musical tone by the amplifying of certain sound waves. Why is this important in a piano? (*Courtesy Research Department, Mason & Hamlin Co.*)

piano strings which produce notes of high pitch are short, thin in diameter, less dense than the bass strings, and very tightly stretched. In tuning a piano, one of the strings, usually middle A, is stretched more or less so that it will correspond in pitch with a tuning fork. Then the other strings are tightened or loosened by the tuner to give each the correct pitch for that string. [See Fig. 8–11.]

b) *In wind instruments.* In some musical instruments, a column of air is thrown into vibration. Such instruments include the pipe organ, the saxophone, the trombone, the flute, the cornet, the clarinet, and several others. The pitch of the note depends upon the length of the pipe or tube of the instrument.

In some wind instruments, the air column is thrown into vibration as a jet of air strikes the edge of an opening. The flute is an example. In some cases the lips of the player throw the air column into vibration. The cornet or the trombone furnishes an example. In such instruments as the saxophone and the clarinet a vibrating reed sets the air column to vibrating.

c) *Vibrating rods or drums.* In drums, as well as in the tambourine, a membrane, usually of calfskin, is thrown into vibration by being struck a sharp blow. In the xylophone (zī′lȯ·fōn), wooden bars or rods are thrown into vibration when they are struck with tiny mallets.

179. How is the human voice produced? In the *larynx,* or Adam's apple, there are some folds of membrane which are called the *vocal cords.* In ordinary breathing, these folds of membrane are so loose that no sound is produced when we inhale or exhale.

If we wish to speak or sing, the muscles change the tension of these cords, and they are then thrown into vibration as air from the lungs is forced past them. Thus we see that the *human voice* is produced by the vibrations of the vocal cords. If we are to have *human speech* we need the aid of several other organs, including the lips, the tongue, the teeth, and

the palate. The quality of the voice depends upon the manner in which the sound waves are modified by the organs of speech and by the number of overtones that are present.

Possibly you may be interested to pronounce the various letters of the alphabet to learn which speech organs are used in pronouncing each one. You will find that the vowels can be pronounced by the vocal cords with little or no help from the other speech organs. But how do you use your lips in pronouncing the letters *b* and *m*? How do you use your tongue in pronouncing the *c* or *s*? How do you form the sounds of other consonants?

*180. **How does the phonograph work?** It occurred to Thomas A. Edison that it ought to be possible to engrave sound waves upon a wax cylinder and then to reproduce the original sounds at any time. With such an idea in mind, he invented the *phonograph.* The word itself comes from the Greek words *phonein* and *graphein,* which mean *to sound* and *to write.* The making of a record consists in permitting the sound waves to cut or engrave a permanent record.

A mouthpiece with an elastic disc may be used in making the record. When one speaks into the mouthpiece, or plays some instrument before it, the sound waves that are produced are concentrated by the mouthpiece upon the elastic disc. The sound waves throw the disc into vibration. To the center of the disc a sharp *stylus* is attached in such a manner

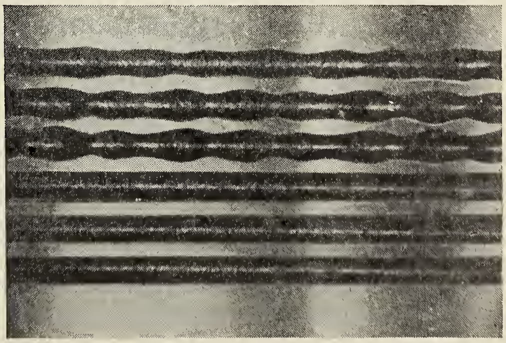


FIG. 8–12. Tracks made in a record by the stylus. The upper three tracks represent actual recordings of a human voice. The lower three tracks were made by the machine without any voice being recorded. (*Courtesy Thomas Edison*)

that it will cut in a soft record a groove of varying depth, or trace in the record a zigzag line. [See Fig. 8–12.]

The record that is thus made is plated with copper, to make a master record. During the plating, ridges will be formed on the copper plate which correspond to the cuts and depressions of the original record. The copper plate is then used as a master record from which thousands of copies can be made by pressing it down upon hard rubber, *condensite,* or some other composition.

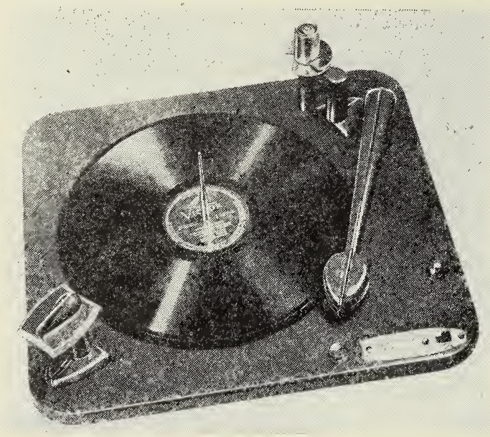


Fig. 8–13. Phonographs reproduce sounds from records. When the sounds are amplified, they may resemble closely the original sound. Why do you suppose the radio has not eliminated the phonograph? What part does the phonograph play in radio? (*Courtesy R.C.A.-Victor*)

The reproducer, shown in Figure 8–13, has a *diaphragm* made of *mica* (mī'kȧ), a mineral which can be separated into very thin sheets; thin metal; or several thicknesses of rice paper shellacked together. A lever is attached at one end to the center of the diaphragm, and at the other end to a needle, made of steel or some hard metal. As the record is turned by means of a turntable, the point of the needle follows the grooves of the record and throws the diaphragm of the reproducer into vibration and thus reproduces the sound waves. A horn is used to *amplify,* or intensify, the sound.

At the present time, records are electrically cut. A special telephone transmitter picks up the sound vibrations and changes them into electrical currents, which are amplified

FIG. 8–14. The dictating machine works on the same principle as the record-maker. Why is it a useful machine? (*Courtesy Dictaphone Corp.*)

by means of a vacuum tube in much the same manner that radio waves are amplified in your radio set. The currents vary with the sound vibrations. These currents operate a recorder which cuts the record in a disc of soft wax. Records which are cut by electrical means give much better tone quality than records of the older type can possibly produce. The low vibration rates and also the high ones are more faithfully reproduced on the electrically cut records and the *s* and *sh* sounds of speech are better.

*181. **How does the dictating machine work?** The dictating machine of Figure 8–14 is much used in offices. An official speaks into the mouthpiece and his voice is recorded on a cylinder. A secretary removes the record and transfers it to a reproducing machine. She then listens to the dictation through small tubes leading to her ears, and usually she types the message at the same time that she is listening.

Questions

1. When you munch a piece of dry toast, why does the sound seem so loud to you?

2. Why does a violin sound much louder to you when your chin is resting upon it than when you are farther away?

3. Persons who are hard of hearing listen to piano music by resting their hands and heads upon the piano. Explain why.

4. Do you think that sounds of different pitch travel at the same speed? Give a reason for your answer.

5. Explain why sounds seem louder at the base of a mountain than they do at the top of the mountain.

6. Make a list of as many ways as you can in which echoes are useful.

7. How does changing the speed of a phonograph affect its pitch?

8. Why do the echoes of an empty hall usually disappear when the hall is filled with people?

9. A man counts 10 seconds between the time he sees a flash of lightning and hears the thunder. If the velocity of sound is 1120 feet per second, how far distant did the lightning occur?

10. How may a violinist change the pitch of the strings in tuning a violin? How may he change the pitch as he plays a violin?

Some things for you to do

1. Make a simple telephone by taking two round pasteboard boxes, such as oatmeal boxes. Punch a hole in the center of the bottom of each one. Use a piece of light, strong cord long enough to reach from your house to that of a neighbor boy or girl. Run one end of the cord through the hole in each box and tie the free end to a piece of matchstick. When the string is stretched fairly tight, the sound waves set up as one person speaks into one box are carried along the string, and they can be heard by a second person listening as he holds the open end of the other box to his ear.

2. Look up "Whispering galleries" in some encyclopaedia or physics textbook, and report to class upon the subject.

Our Bodies Are Built Like Machines

The human ear, although remarkable in itself, is only one part of the larger and even more remarkable structure – the human body.

Unit 5 tells something about the history of the human body, how it developed from simple beginnings, how its parts were tested, how certain changes that were useful to it became permanent structures that were carried on from generation to generation. As you study this unit on the human body, you will see how the parts of the body, like the parts of a machine, have their purpose and their reason for being parts of the whole. You will form some idea of the stupendous amount of time it has taken to test the parts of the human body. Perhaps you will gain a new respect for the human machine and a new interest in keeping it in good running condition.

During these millions of years other forms of life have been developing along with human beings. You will read about

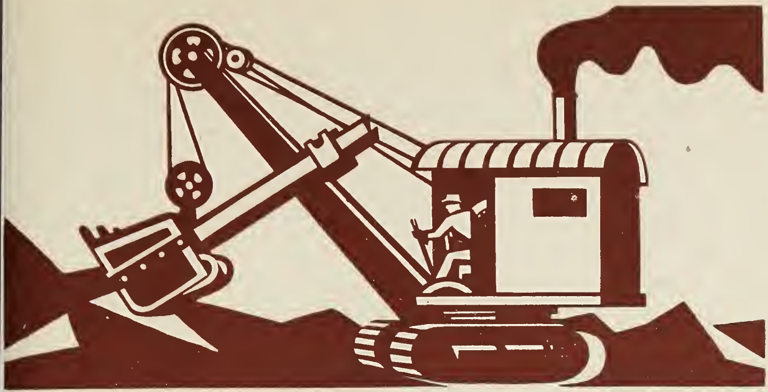
the pioneer fish which developed lungs and so could breathe on land. You may wonder what invisible changes are going on now — what tests are being made in the bodies of human beings, and what tests are being made in the lesser machines — the bodies of other animals.

Think about these!

1. Are our bodies different from those of the earliest and most primitive men?
2. How many organs have you in your chest?
3. Do you know what is the smallest organ and what is the largest organ in the body?
4. Do you know out of what material your body was built?

Words for this chapter

Appendages (ă·pĕn′dĭj·ĕz). External organs or limbs.
Colchicine (kŏl′chĭ·sēn). A chemical which causes mutations in plants.
Mutants (mū′tănts). A striking change passed on to a new generation.
Diaphragm (dī′ȧ·frăm). As used here, a muscular wall in mammals, separating the chest cavity from the abdomen cavity.
Thorax (thō′răks). The part of the trunk in higher animals between the neck and the abdomen.
Intestine (ĭn·tĕs′tĭn). The tubular part of the alimentary canal.
Proteins (prō′tē·ĭnz). Substances necessary for the manufacture of all living cells.
Gland. A structure or organ of the body more or less hollow, which is useful to the body because of its secretion.



CHAPTER 9 _______________ UNIT 5

What Is the Plan of the Human Body?

182. What sort of beings would you find on an unknown world? Suppose you were able to take a trip beyond this earth into space; a tour which finally ended on an unknown world. And suppose that on this unknown world you found strange living creatures, with some parts like our animals and other parts very different. You would undoubtedly be puzzled by many of the things you saw; but the more you studied the new *organisms,* or living beings, the clearer it would be that each of their physical structures was used for some special function. There would probably be some parts designed to take in and to give off gases, that is, to breathe. Other parts, perhaps resembling legs or wings or fins, would be necessary for movements and locomotion. Some structures would be needed to protect the interior of the animal. And surely there would have to be some kind of sense structures such as eyes or ears to help the animal to be aware of good things like food, or of enemies like hostile animals.

183. How useful are the structures of animals? Such a trip might set you to thinking about the usefulness and even the necessity of the various structures that make up the bodies of the animals you know here on this earth – the legs, tails, fins, feelers, wings, scales, and hair, for example. You might also wonder about internal parts, such as the muscles, bones, and nerves; and many special organs, such as the lungs, heart, and stomach. How did these bodily parts come to have the form that you see now? Were the animals that lived millions and millions of years ago very different from present-day creatures? Or have there been no important changes? Was a horse or a cow always a horse or a cow as today?

Such questions lead to very interesting answers. Only a few of these answers can be considered here.

184. How do fossil animals compare with the animals of today? The stories that the fossils tell us are dependable.

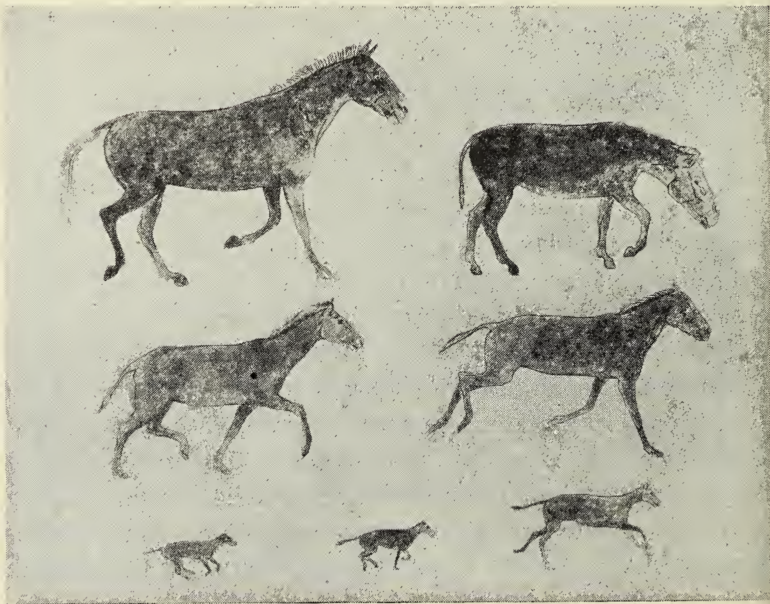


FIG. 9–1. Fossil remains give us this story of the development of the horse. (*American Museum of Natural History*)

They tell us that living forms have gradually been changing through the ages. Since life as we know it has never been created by man but comes only through the reproduction of living creatures, the animals and plants of today must be the descendants of animals and plants of the past. If we compare the horse of today with different kinds of fossil horses, we find that the ancient horse was much smaller than the modern horse. The earliest horses were no larger than dogs, and walked with several toes on each foot; whereas the horse of today is very much larger and walks on one toe of each foot. [See Fig. 9–1.] In fact, the hoof of the horse is an enlarged toenail. From examining fossil camels, we know that the camel, too, was formerly smaller than now and had four toes on each foot instead of two divisions as at present. Sharks formerly were enormous creatures, some of them being as long as two ordinary houses. Through ages of development they have become reduced in size. Trees, in ancient times, were really enormous ferns, with scales all over the trunks. [See Fig. 9–2.]

Fig. 9–2. The trees of ancient times were like huge ferns with scaly trunks. This fossil shows some of the leaves of such a tree. (*American Museum of Natural History*)

From fossils we know that the ancestors of many of our present land animals were creatures which lived in the water and were provided with structures such as gills and fins, or paddle-like *appendages.* On the other hand, many scientists think that the small, deeply hidden leg bones found in the whale are evidences of the fact that whales long ago lived on land, and later for some unknown reason took to the water. Although whales never acquired gills for breathing in the water, they have enormous tails necessary for pushing their huge bodies through the denser medium, water.

Most of these things happened so long ago that it is impossible to realize what tremendous periods of time are involved. The fossils we have been considering were made, according to many scientists, perhaps several hundred million years ago, long before there were any human beings on the earth or any domesticated animals. They represent the oldest remains of living things. And the changes in structure must have come slowly through long periods of time.

185. Is it true that animal structures change from generation to generation? It is being proved today that plants and animals *can* be changed. Men who breed plants and animals have developed hundreds of new species. Their method is simple. They select those individuals which show changes that are wanted. By continued breeding and selection, the breeders can finally get forms that are different in size, color, and parts, from the forms with which they started. In fact, the different kinds of dogs [see Fig. 9–3], many of which you can name, furnish an example of how much one animal can be changed under man's influence. It is generally agreed that all kinds of dogs are descendants of a wolflike or foxlike ancestor which was finally domesticated.

In the laboratory, too, it has been proved that plants and animals can be changed. By putting a certain chemical known as *colchicine* on seeds, and by exposing eggs to X rays, scientists have produced many changes in structure resulting in new kinds of plants and animals.

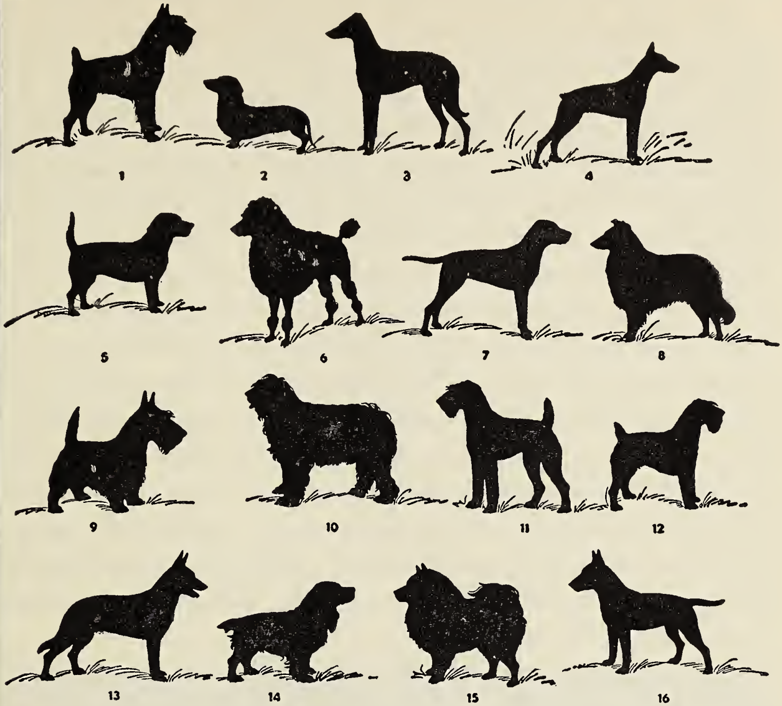


FIG. 9–3. Scientists today generally agree that the many breeds of dogs have been developed from some wolflike ancestor. How many of the breeds pictured here can you recognize without reading the key which follows? 1. Giant Schnauzer. 2. Dachshund. 3. Whippet. 4. Doberman Pinscher. 5. Beagle. 6. Poodle. 7. Pointer. 8. Collie. 9. Scottish Terrier. 10. Old English Sheep Dog. 11. Airedale Terrier. 12. Miniature Schnauzer. 13. German Shepherd Dog (Police Dog). 14. Cocker Spaniel. 15. Samoyede. 16. Bull Terrier. (*Courtesy Abercrombie & Fitch*)

186. Are two leaves on any tree identical? It is well known that animals, even of the same kind, vary. Twenty Plymouth Rock hens may at first glance seem to be identical. Closer examination will show individual differences in color, weight, running ability, egg-laying capacity, and other characteristics. In the same way, although the leaves of a white oak tree all appear at first glance to be alike, no two leaves on any one tree of this species can be found that are identical.

187. What are mutations? In addition to this common kind of variation, there sometimes occurs in nature an individual plant or animal that varies much more than usual. It is markedly different from its parents in some detail. And the most important thing about it is that the same change in structure occurs in the offspring of this new individual. This kind of change is called a *mutation*. An example of a mutation among animals is the Ancon ram. During the Revolutionary War, a peculiar lamb was born among the flocks of a Massachusetts farmer. This animal had shorter legs and a wider body than the other lambs. It grew up to be a very heavy-bodied ram, whose stout legs prevented it from jumping the fences of that time. This animal passed on its chief characteristics to its offspring. Thus the famous Ancon sheep came into existence. It is valued today, especially in Australia, both for wool and for meat. Many cases of *mutants* among animals have been recorded. Hundreds of such changes in the fruit fly have been recorded.

188. Are mutations helpful or harmful? Some mutations help the animal or plant. Other mutations, however, are of no advantage and may even be a disadvantage to the organism. For instance, one mutation among fruit flies occurred in a biology laboratory. This was a shortening of the wings, so that these individual fruit flies were almost wingless. If this mutation had happened in nature, it would have doomed such flies to an early death and would have wiped out the new species.

One of the important things to remember in thinking about such biological stories is that the animals that survived the combats and dangers of those ancient years were probably the ones that possessed mutations that they found useful. Remember that their offspring inherited the same structures. On the other hand, in long periods of time, animals that lacked helpful mutations were more likely to perish. Which of these two types of animals, then, would be the more likely to have descendants? Why?

189. How have living things advanced by means of mutations? It is probable that by means of mutations, some living forms have been changed through the ages. It would seem to be true that any animal that possessed a helpful mutation had a better chance of living a normal life and of having descendants, than the same kind of animal would have had without the mutation. For example, scientists believe that certain water animals developed gills. This mutation was beneficial because it enabled these animals to get more oxygen for releasing energy. That is, animals with gills must have had a better chance to live and to have offspring. And animals that developed lungs instead of gills could come out of the water and begin to live on land. [See Fig. 9–4.] The lungfishes are an example of that fact today. These animals are fishes with true gills. In addition, their swim bladders are connected by a tube with the throat. Thus they can take air into this bladder, which is closed in most other

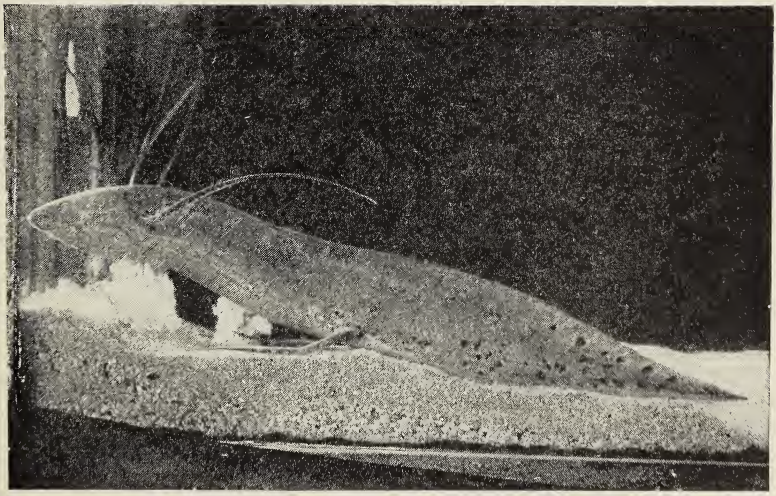


Fig. 9–4. The lungfish resembles other fishes in having gills. But it also has a simple lung with which it breathes air when out of the water. Thus in both structure and function, the lungfish is advancing beyond ordinary fishes. (*American Museum of Natural History*)

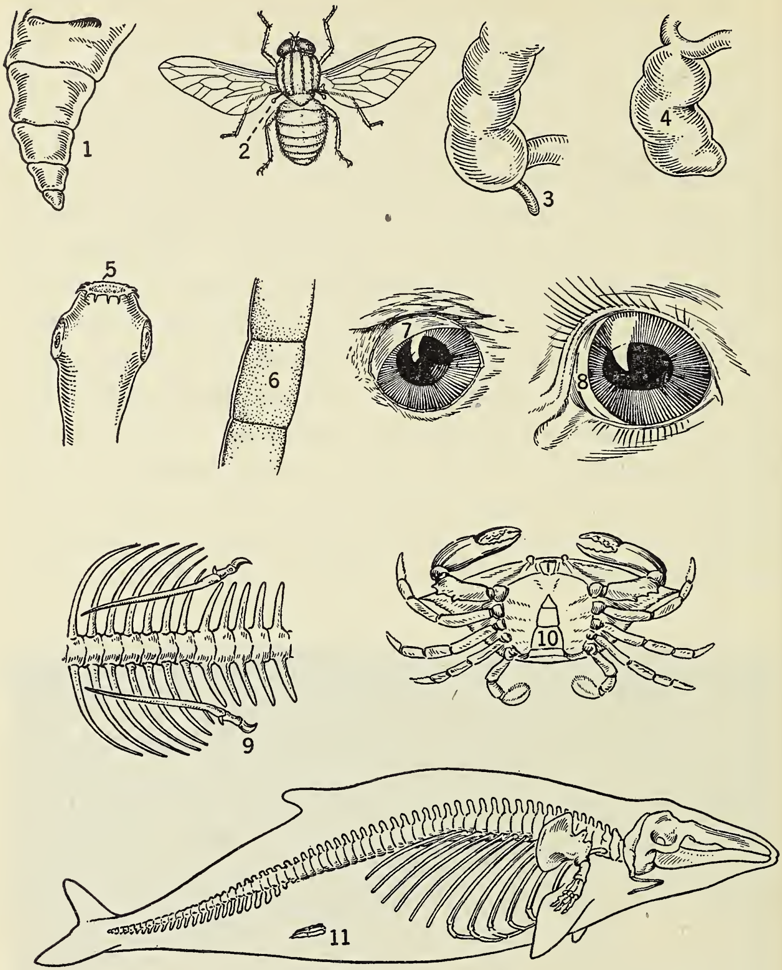


FIG. 9–5. The useless lapel buttonhole and sleeve buttons are vestiges of former styles in men's clothing. Animals, too, have vestigial parts, remnants of former body "styles," now quite useless to them. 1. Internal tailbones, gorilla. 2. Minute hind wings, fly. 3. Useless appendix, man. (4. Functioning appendix, porcupine.) 5. Mouthless head, tapeworm. 6. Legless segment, tapeworm. (7. Functioning third eyelid, bird.) 8. Vestigial eyelid, horse. 9. Internal legbones, snake – python. 10. Limited abdomen, crab. 11. Internal legbones, porpoise.

fishes. The swim bladder of these fishes thus becomes a true air bladder or primitive lung.

The first lung-bearing animals, as they continued to live on land, probably developed legs and feet instead of paddles or fins. Many other changes must have taken place. In fact, scientists believe that animal life, and plant life too, to a lesser degree, has been changing its forms and structures even up to the present day. Every structure, every new mutation, has been tried out. If it contributed to survival, it was retained and passed on down to the offspring. So it is that the organs and structures of the body of an animal you see today are the results of a long history of changes as each part developed into practical use in the bodies of the ancestors of that animal. In the development of organisms through the ages, there are many instances of a structure's ceasing to be of use. Such parts, remnants only of organs that formerly functioned well, may remain and appear in generation after generation. Structurally they get smaller and more useless. Such organs are called *vestigial* (vĕs·tĭj′ĭ·*ăl*) organs. The hind wings of a fly, the abdomen of the crab, and the hip bones of a huge snake, are all examples of vestigial organs. [See Fig. 9–5.]

190. What are the internal organs of a frog? The story of development explains the general structure, external and internal, of any common animal such as a frog, a cat, or a horse. It is usually not possible to observe the internal organs of a large animal. But an animal such as a frog is easily obtained. Its internal structure is much like that of larger animals. The dissection and examination of a chloroformed frog can have great biological importance for science students. The frog has no *diaphragm* such as man and the other mammals have; so it does not have the two body cavities, the chest and the abdomen. However, the dark red heart and the grayish lungs, which occupy the chest cavity of a mammal, can easily be observed. Most of the other internal organs of a mammal are also to be seen as one explores.

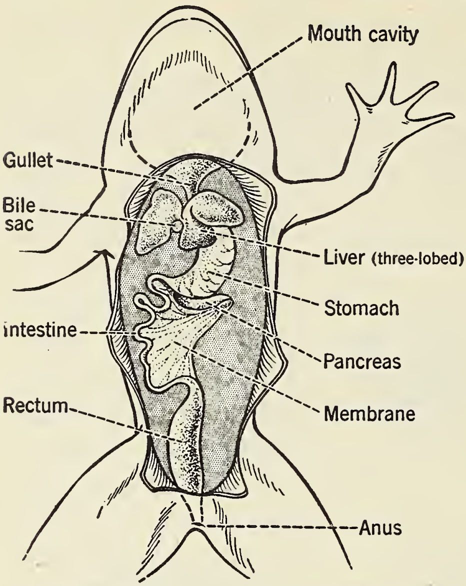


FIG. 9–6. The digestive system of the frog is essentially like that of a human being. The alimentary canal, or food tube, extends from the mouth to the anus. The digestive glands, which include the liver, the gastric glands of the stomach, and the pancreas, pour digestive juices on the food. A membrane supports the intestine and blood vessels which carry digested food to various parts of the body. Wastes are passed off from the anus.

[See Fig. 9–6.] Each of these internal organs has been tried out in the lives of countless ancestors of the frog, and functions now because it has been found necessary to the life of the animal.

In the male frog one can find an interesting example of a vestigial, or functionless, organ. Underneath each kidney is a tiny, coiled, now-useless *oviduct* (ō′vĭ·dŭkt), or tube for carrying the eggs.

This examination of a frog is an excellent introduction to the study of the human organs and their functions.

*191. **How does the human body develop from the embryo?** Human beings are distinguished from what we call the lower animals chiefly by mental and spiritual powers. From a physical standpoint, although human beings may seem very different, they have about the same internal organs as other vertebrates.

The human body starts from a tiny *egg* cell not much bigger than a grain of dust — a thing about as large as the smallest dot you could make with your pencil. After this cell has

been fertilized by a *sperm* cell, itself so small that it cannot be seen except by the use of the strongest microscope, the egg begins to divide into many cells.

This little living thing of many cells is called an *embryo*. It goes through several stages of development. First it grows and becomes hollow, with only one layer of cells on the outside. This is called the *ectoderm* (ĕk′tȯ·dûrm); *ecto* means *outside*, and *derm* means *skin*. Then one side seems to be pushed in like an old, crushed rubber ball. The buckled-in portion becomes an inner layer, that is, a second layer of cells. This is called the *endoderm* (ĕn′dȯ·dûrm); *endo* means *inside*. Between these two layers of cells a third layer of cells forms. This is called the *mesoderm* (mĕs′ȯ·dûrm); *meso* means *middle*.

The first layers of cells of the human body are very important because the entire body grows from them. The ectoderm will become most of the skin; the sense organs of the head, such as the eyes and ears; and the brain and nerves of the body. The endoderm will become most of the internal organs, such as the intestines, the liver and the digestive glands, the lungs, and the bladder. The mesoderm furnishes material from which is eventually formed the rest of the parts of the body: the muscles, bones, heart, blood vessels, blood, kidneys, and reproductive organs. These three layers of cells, since they are the beginning layers, are usually called the *primary germ layers*.

Following the development of the three layers, the embryo which will become a man continues to grow. Head, back, and crude arms begin to develop. Two chambers of the heart are formed, and later another two chambers are formed, so that the heart finally has four chambers.

Later a cord appears in the back and develops into the backbone. Arms and legs as we know them can be recognized, and the embryo has grown into a human body.

Soon the baby has all the parts needed for life by itself, and the child is born.

The body continues to develop after birth. The child begins to cry, using lungfuls of air; and breathing continues throughout life. Bones grow and muscles develop. The child becomes more and more able to do what it desires to do. After a few years the child has developed enough control of lungs, tongue, lips, and vocal cords to talk. Changes more or less noticeable continue throughout life.

The continuous growth of the embryo into a mature man or woman is without exception the greatest of all marvels, the greatest wonder of the world. The course of development for the tiny embryo seems to be charted, and growth follows the usual pattern with but few exceptions.

Thus the boy or girl is provided with a physical body which he or she keeps throughout life. Health and happiness may depend upon how this body is cared for and whether the physical desires and emotions are controlled by the mind. It is a remarkable instrument — this body — made up of many organs.

192. What is the internal structure of the trunk? The human trunk contains two large cavities, separated by the thick muscular curtain, the *diaphragm.* This diaphragm aids in breathing. It is this organ that suddenly contracts and moves up against the lungs, thus forcing air out and causing a sneeze or cough. A hearty laugh also starts with the vibration of the diaphragm. This diaphragm is located just below the breastbone. Above the diaphragm is the chest cavity, or *thorax.* Below is the *abdominal* (ăb·dŏm'ĭ·năl) *cavity,* or abdomen.

193. What internal organs are there in the chest cavity? The chest cavity is filled with two spongy, pink *lungs* (one on each side) and the four-chambered *heart,* the hardest working organ in the body. The heart is about the size of your clenched fist, and is suspended, point downward, slightly to the left of the middle of the chest. The lungs and heart are covered on the exterior with a smooth skin. The same skin lines the inside of the chest cavity. A liquid is passed off

from this lining which makes the lungs and heart very slippery. Thus there is very little friction between these organs and the lining of the chest cavity. Otherwise, holes might be worn in the lungs or the heart as they move back and forth, just as holes are made in stockings or suits by too much friction with other objects. You can buy another pair of stockings and another suit if either wears out. You cannot get a new heart or new lungs. The organs with which you were born are the only ones you will ever get.

There are some very important blood vessels connected with the heart and extending like water pipes through the chest cavity. There is also the windpipe leading down to the lungs. It is important that this tube be kept wide open all the time so that air can go in and out. In order to accomplish this, the walls of the windpipe are stiffened with rings of cartilage. You can feel these rings in your own throat. One more big tube extends down through the chest cavity, the gullet or food tube. This tube has muscles in the walls to squeeze or push the food down. This process is *swallowing*. The gullet is the upper part of the food tube, or *alimentary canal,* which extends through the trunk from the mouth to the *anus* (ā'nŭs), or lower opening of the alimentary canal.

194. What other internal organs are there in the body? Just below the diaphragm lies the big enlargement of the food tube called the *stomach*. From this organ the food tube continues in the form of the *intestines*. The stomach aids in digesting some of the food, but it is more of a temporary storehouse for food. On the right of the stomach is the largest organ of the body, the *liver*. The liver stores excess sugar and destroys excess *proteins* and red blood cells. It also manufactures *bile*, which is needed to help digest fat and oil in the small intestine. It stores the bile until needed, in the bile sac, sometimes called the *gall bladder*. Underneath the stomach is the most important digestive *gland* in the body, the *pancreas*. This furnishes *pancreatic* fluid, the most valuable digestive juice in the body. The

pancreatic fluid is passed off through a tube, or *duct*. In the midst of the intestines is the *spleen*, an organ in which old red blood cells are destroyed. At the back of the abdominal cavity is the pair of *kidneys*. As the blood flows through these organs, the *wastes* are taken out and pass down into the bladder, directly below.

The internal organs of the chest and the abdomen are fairly prominent organs. In addition there are in the body several organs so small and inconspicuous that you would certainly miss them unless you knew just where to look for them. These are the *ductless* glands – glands which have no ducts or tubes as outlets for their secretions. Although some of them are hardly larger than a marble, yet these glands are perhaps more important than any other organs in the normal development of the body.

In the head, underneath the brain, is the master ductless gland, the *pituitary* (pĭ·tū′ĭ·tĕr′ĭ). Its secretions determine the growth of the bones and the general development of the body. The *thyroid* (thī′roid) gland in the front of the neck regulates the rate at which the body organs work. This gland is a sort of " governor " for the body machine. The *adrenal* (ăd·rē′năl) glands connected with the kidneys tend to speed up body activity, when necessary. The *pancreas* is a ductless as well as a duct gland. Its ductless part assists in the oxidizing of sugar. There are several other ductless glands. The secretion of a ductless gland is called a *hormone* (hôr′mōn), and is absorbed directly by the blood.

195. What are vertebrate structures? Most of the animals on earth belong to the group called *invertebrates*. They have no backbone. Instead most of these invertebrates are soft-bodied. [See Fig. 9–7.] The other large group, called *vertebrates*, have a spinal column of separate bones. They have only two pairs of limbs, and they all have an internal skeleton. Vertebrates are animals such as fishes, frogs, reptiles, birds, and mammals. Human beings belong to this group.

FIG. 9–7. Most invertebrates have rather soft bodies like that of the earthworm. They are distinguished from vertebrates by the absence of an internal skeleton. (*Courtesy of the Bruce Museum*)

196. Do the organs of the body work together? All the organs that make up the body must work together for the good of the individual. Unless co-operation exists among the working parts of the body, including the internal organs, the skeleton, muscles, skin, and blood, ill health is bound to follow. Each function is dependent upon other functions. Digestion may be the special work of the alimentary canal, but it is influenced by the condition of the nerves. Thinking is not a matter solely of the brain and mind. It is hindered by fatigue of muscles, secretion of glands, congestion (excessive accumulation) of blood, indigestion, drugs, and poisons from bacteria. Health, then, means unity of action for all parts of the body.

197. Do human beings have vestigial organs? Not all the organs found in the human body appear to be useful to man. Some seem to be the remnants of organs that once might have been active and valuable. For instance, at the beginning of the large intestine, there is a small tube attached to the intestine, called the *appendix,* which does not serve

man in any useful way today. In fact, it is a hazard, for sometimes it gets inflamed and has to be removed. In the corners of our eyes, there is a skin which seems to be the remains of what is the third eyelid. There are many more vestigial organs in animals. [See Fig. 9–5.]

***198. What advantages and what disadvantages come to man on account of his erect posture?** Human beings, unlike most other living creatures, have erect posture. Human beings balance themselves upon two feet instead of four. This position has brought with it several interesting problems.

a) The human body rests upon two instead of four feet, and the center of gravity is high. These facts bring a special danger not shared by quadrupeds (kwŏd′rŏŏ·pĕdz), or animals that walk or run on four legs – the danger of falling. These two facts mean also for human babies a prolonged period of learning to balance the body so as to walk, and somewhat later to run, dance, and skate.

b) With erect posture, the internal organs tend more to pile up and rest on each other, in a vertical line, causing pressure on the lower organs from the extra weight of the organs above. When ill or tired, human beings lie down to relieve this strain. Such results do not happen in dogs, horses, and other quadrupeds, which " walk on all fours " and whose internal organs lie more or less side by side.

c) The entire weight of the body is borne by two feet instead of by four. This is one of the reasons for the excessive foot trouble from which many human beings suffer.

d) In human beings, important arteries, nerve centers, and the soft-walled abdomen are not protected by being underneath the rest of the body. Thus they are exposed to injury from blows and collisions.

e) The windpipe, instead of opening forward as in quadrupeds, opens directly upward in man, with a correspondingly greater chance for the entrance of substances and resultant choking.

In spite of these disadvantages, there is a great advantage that has come to human beings from the erect posture. This is entire freedom for the arms, which if used as in quadrupeds would be the front limbs. This circumstance has resulted in the development of the hands into the most wonderful living tools in the world.

Man has sufficient intelligence to overcome the difficulties brought on him by the erect posture. Long practice gives man a mastery over his body movements possessed by no other animal. [See Fig. 9–8.] Bodily fatigue is dissipated, or got rid of, by rest and massage, and by a change of activity. The wearing of correct shoes and prompt attention to foot troubles when they are first noticed will prevent most foot ills later. Good judgment and care will avoid most abdominal injuries. Leisurely eating habits will send food and drink down the right channel and not down the windpipe.

Fig. 9–8. A dancer like Fred Astaire develops his natural ability by long and intensive practice. His muscles and bones have been so well co-ordinated with his nervous system that remarkable body movements are possible. (*Culver Service*)

199. **Is man superior to the " lower animals "?** We have seen that from a physical standpoint the human body, in its general structure and internal organs, rather closely resembles the bodies of many other animals. Yet all other animals

are generally regarded by man as lower animals. And so they are, for man in mental and spiritual capacity is far above any other living creature. The animals which we like as pets often reveal genuine intelligence and devotion. But left to themselves, they would often be helpless or savage. Man, through his ability to understand himself and his environment, has become the master of a large part of the world. He has developed telescopes to search the universe, and microscopes to reveal the minuteness of things about him. He has arranged a plan of education occupying from a quarter to a third of the life span. He has developed forms of democratic government for the purpose of making possible a useful, happy, and thoughtful life. He has formed standards for valuing kindness, honesty, and unselfishness. He is constantly trying to understand and communicate with the infinite and eternal, for he considers himself a part of it. Man's mental capacity seems to exceed that of his most intelligent pets by a huge margin. His spiritual capacity, when developed, may make man feel that he is a partner in an eternal plan.

Questions

1. In the development of animals through the ages, which do you think came first, gills or lungs?
2. How do you account for the presence of flightless birds on islands?
3. What conditions may cause animal structures to change?
4. How large were the earliest horses? How do you know?
5. What part of your hand corresponds in structure to the hoof of a horse?
6. How are fossils of value to us today?
7. How are new types of plants and animals developed in nature?
8. How do men develop new types of plants? How do they develop new types of animals?

9. What have biologists been able to accomplish by the use of colchicine?

10. Define *variation.* How do you account for variations in plants and animals?

11. Give examples of mutation. Are new mutations always beneficial to the individual? Are they ever harmful?

12. What is the most primitive lung?

13. What reasons would you give to show that a human being is an animal rather than a plant?

14. What are the important steps in the development of the human embryo from the fertilized egg to babyhood?

15. What organs are found in the chest?

16. What vestigial structure of the human abdomen is often dangerous? Discuss.

17. What are some of the important organs found in the abdomen?

18. What price does the human race pay for its erect posture?

19. What is a ductless gland? How are ductless glands important?

20. What is the most wonderful living tool?

Some Things for You to Do

1. Note the parts of a chicken or other fowl as it is being dressed in the preparation of a meal.

2. Observe the parts of the body and their arrangement as revealed after the butchering of a pig, sheep, or cow.

3. Under the direction of your teacher or some other experienced person, dissect a frog or some other animal which has been killed by accident or by an anesthetic such as ether or chloroform.

4. Visit a museum to see fossils of prehistoric animals, vestigial leg bones of the python, and human embryos.

5. See if you can find two leaves on the same tree that are identical in size, shape, and parts.

6. Read about mutations caused by colchicine and X rays. Write a report on the most interesting of these mutations. If you like, you may write the report in the form of a story, or perhaps as parts of the diary of the scientist performing the experiments.

Think about these!

1. How many bones have you in your body?

2. Have you more or less mineral matter in your bones than your father has?

3. Do you know that there is a tiny gland that may make giants or dwarfs of us if it does not function properly during youth?

4. Are you eating the right food for good muscle development?

Words for this chapter

Ligaments. Bands connecting two bones at a joint.

Socket. A cavity in a bone into which the head of another bone fits.

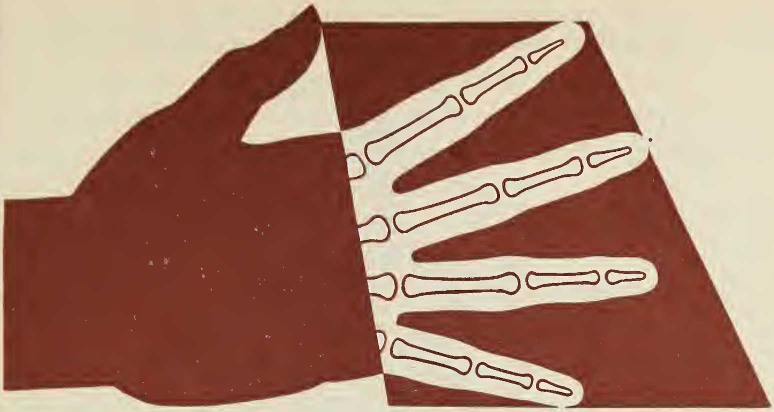
Vitamins (vī′tȧ·mĭnz). Substances in certain foods, necessary for health and to prevent specific diseases.

Pituitary (pĭ·tū′ĭ·tĕr′ĭ). One of the ductless glands located in the head and governing the growth of the skeleton.

Laceration (lăs′ẽr·ā′shŭn). A wound made by tearing.

Protoplasm (prō′tō·plăz′m). Any living matter; the essential life substance making up the cell.

Inferiority complex. The constant fear that one is not so good as others in some way.



CHAPTER 10 ________________ UNIT 5

Why Do We Have Bones and Muscles?

200. How many bones have you in your body? Each one of us has over two hundred bones in his body. Each of these bones is of little or no use alone. But as a part of the body, working with other parts for the common good, it becomes of great importance. Even one slightly misplaced bone, such as a vertebra of the back, by pressing upon some nerve, may cause great suffering and even disease elsewhere in the body.

The skeleton consists first of the 22 skullbones, which in turn rest upon the 26 bones of the spine, to which are attached the 24 ribs. In front, most of the ribs join the *breastbone,* or *sternum.* Each arm and hand has 30 bones, and each shoulder has two bones. Each leg and foot has 30 more, and each hip finally adds 2 pelvic bones. [See Fig. 10–1.]

201. Can there be a boneless man? Perhaps some of you boys and girls who are reading this chapter have seen or have heard of the "boneless man." He usually turns out to be

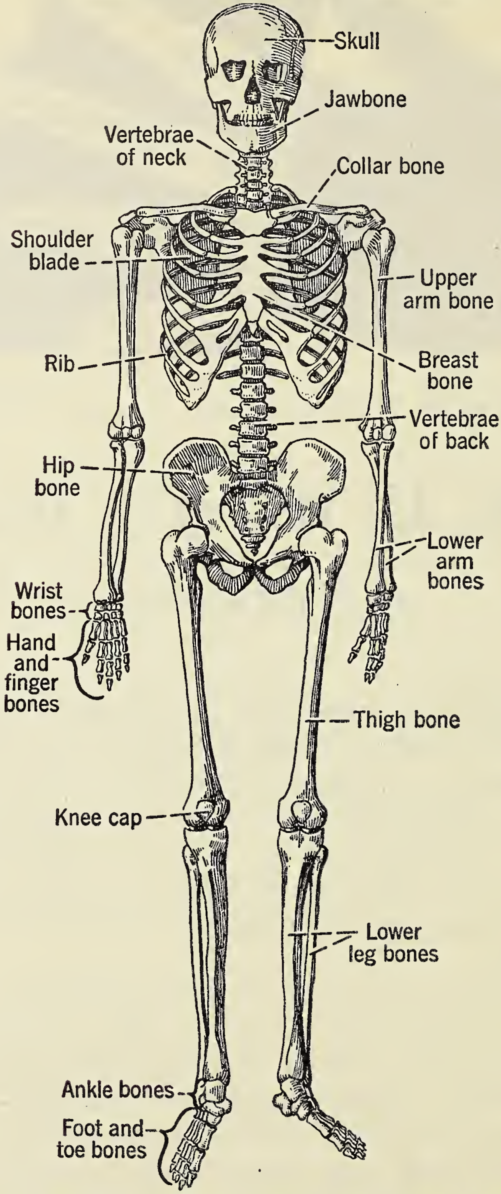


FIG. 10–1. It would be quite a task to count and to name the more than 200 bones in the human skeleton. But it is not difficult to remember the principal ones shown here and labeled.

a circus freak who is able to bend his body and limbs almost in all directions. Actually it is always found that he has a skeleton, though his bones may be somewhat smaller than usual and his joints loosely connected.

Would you be surprised to learn that each one of us is truly boneless at one stage of our development? In the early human embryo there is no skeleton. The nearest approach to it is the rod of rubberlike cartilage in the back. This later develops into the *backbone* (vertebral bones). The bones of the skull and of the arms and legs begin to form at the same time. Why do bones develop in vertebrates and not in soft-bodied, invertebrate animals? Evidently there is going to be a need for them, later, in the vertebrate animals. The skeleton must be ready for its work, or the animals concerned cannot survive.

202. How are bones valuable to vertebrates? No one knows just when or how bones began to develop *inside* the body of animals. We only know that vertebrates, with their *inside skeletons*, appeared much later in the scale of life than did the invertebrates, some of which, like the lobster, the crab, and the beetle, had a sort of hardened covering over their bodies called the *exoskeleton* (ĕk′sō·skĕl′ē·tŭn). It is true that the vertebrates, partly on account of their skeletons but more on account of their brain and nervous system, are considered to be higher animals than are the invertebrates. The important brain and spinal cord of the vertebrates are protected from outside dangers by the bones of the skull and of the spinal column. The thick bones of the head also protect the eyes and the ears, so necessary to the life of higher animals. Similarly, the ribs form a bony casing protecting the heart and the lungs. Vertebrates are generally larger than invertebrates. Some vertebrates are huge creatures. The backboned animals that run "on all fours," or that stand more or less erect like man and the apes, depend upon their skeletons to keep their form and to keep them erect. Most bones of the body have muscles

attached to them by tendons. By means of muscles, animals move about, seeking food or shelter, or fighting with enemies. The bones of vertebrates, then, are very useful in protecting vital parts of the body, in supporting the body and thus retaining the body shape, and in making possible the various kinds of locomotion seen in this group.

203. What is a living bone like? Probably not a single boy or girl reading these lines has ever seen a living bone, though everyone has many times seen bones that are white and dry and dead. It is difficult to realize that the hard bones in your body are just as much alive as are the softer parts of your body. Let us look at a bone recently taken from the body of a sheep or a cow, after the animal has been prepared for market. If you understand the parts of a bone, it will be easier to realize what sorts of things are happening in such a bone in a living animal.

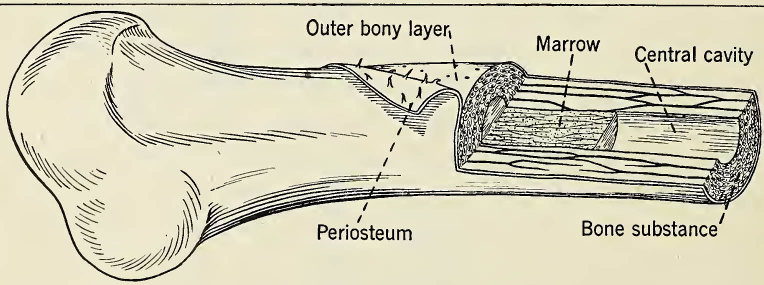


FIG. 10–2. The shaft of this long bone has been dissected to show the parts. Bones are valuable for support and as levers making body action possible. Red blood cells are made in the marrow.

The bone shown in Figure 10–2 is the long bone of the upper part of the leg. You will see that it is hollow through the middle. In this cavity is a yellowish, greasy substance called the *marrow*. The marrow found near the ends in long bones is called *red marrow*. Such marrow makes red blood cells. As these tiny discs are formed, they are passed off into the blood, just like new pennies pouring from the mint. You will notice that the wall of the bone surround-

ng the marrow is very smooth. It is thick and hard and strong. But at the ends of the bone you would find the bone to be porous or spongy. These ends of the bone are sometimes called the *heads* of the bone, and the part of the bone connecting the two heads is called the *shaft*.

204. How are bones fitted together? As you notice, the ends of the bone are somewhat enlarged. Each end is shaped in such a fashion that it fits nicely into the corresponding part of another bone. The place where two bones thus fit together is called a *joint*. In every joint, at least one bone is, or has been, movable, as in our upper arm bone at the shoulder. In some places, both bones are movable, as at the elbow, knee, and finger. Where two bones come together, as at joints, the surface of each bone is covered with a layer of white, smooth cartilage.

A liquid is passed off into the living joint from the membrane lining the joint. This acts like oil in machinery, and helps to reduce friction so that our joints do not get stiff or squeak when we move about. It is remarkable that in normal health this oily substance is secreted automatically without our planning for it, or having to remember to " get some more joint oil for next week's use "! Nor do we have to change oil as in automobiles.

Where two bones meet at a joint, they are held in place by strong bands of white tissue, called *ligaments*. Surrounding muscles also assist in keeping bones in place.

205. What kinds of joints are there? If you examine your joints, you will find that there are five kinds, all of them movable except one [see Fig. 10–3]: (*a*) the *hinge joints* of the knee, elbow, toes, and fingers, which act like the hinges of a door or of a gate; (*b*) the *ball-and-socket joints* of the hip and shoulder, where the head of one bone fits into the *socket* of another bone, making possible large movements of the arms and the legs; (*c*) the *pivot joint* in the neck, where the *atlas* bone on which the skull rests, turns about on the *axis* bone underneath it, thus making possible

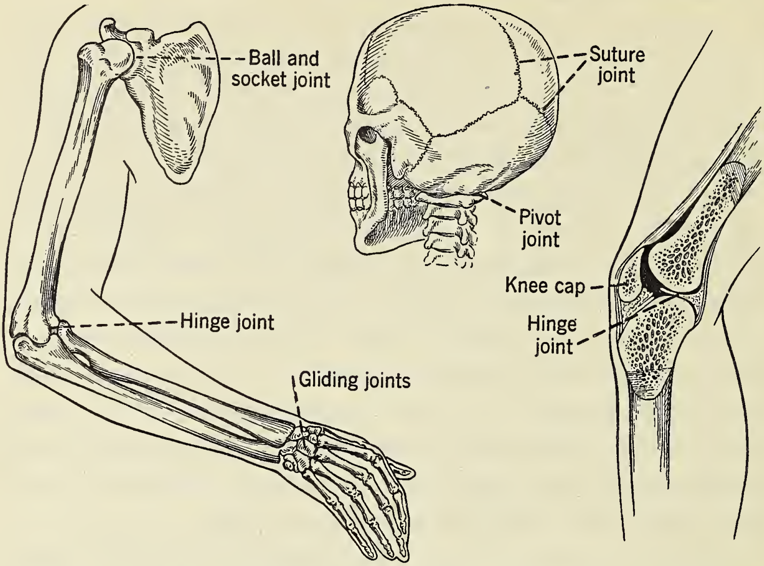


FIG. 10–3. There are five types of joints in the human skeletal structure. By moving your wrist, you operate the gliding joints; by moving your lower arm, you move the hinge joint at the elbow; by moving your shoulder you move a ball-and-socket joint; by moving your head up and down and from side to side, you operate a pivot joint. The suture joints, in the skull, are not movable.

the shaking of the head; (*d*) the *compound* or *gliding joints* of the wrist and ankle, which permit the hand and foot to move in almost any direction; (*e*) the *suture* (sū'tūr) *joints* between the bones of the skull, which are immovable joints.

206. What joint injuries should be guarded against? Several joint injuries are too common. (*a*) Sometimes a bone may slip out of its joint. Such a bone is said to be *dislocated.* If a bone slips out of a ball-and-socket joint, the bone must be pulled away from the body until the ball can slip back into the socket of the joint. This can happen to the leg at the hip, to the arm at the shoulder, or to the jaw near the ear. A person subject to such dislocations must use caution in exercising.

b) When *ligaments,* together with blood vessels and

Fig. 10–4. A sprained ankle should be supported by proper bandaging and then used with care for some time. The bandage should, of course, be put on by someone trained for the job. (*Courtesy U. S. Bureau of Mines*)

nerves, are pulled loose at a joint, a *sprain* occurs. Escaping blood from ruptured blood vessels may make the parts turn "black and blue." The symptoms are great weakness of the part, soreness, and swelling. The alternate use of hot and cold compresses affords some relief. A sprained joint should be properly bandaged by a physician and then used with care. Better results are thus obtained than by complete rest, which used to be prescribed. [See Fig. 10–4.]

c) Sometimes a joint may receive a severe blow or experience prolonged pressure. In such a case too much liquid will probably be secreted by the membrane and the joint will become swollen and painful. The most frequent injury of this type is called *water on the knee,* suffered by football players more frequently than by other athletes. Such an injury may be avoided by wearing knee pads.

d) With advancing age and also with a disease called *arthritis* (är·thrī′tĭs), there may be a decreased amount of liquid secreted in the joint, and there may also be deposits of mineral substances in the joints. There seems to be no certain remedy known to medicine that will cure arthritis, though right diet may prevent it. Mild exercise is beneficial in preventing old joints from feeling their age.

207. How does a bone grow? Over the outside surface of the bone is a membrane called the *periosteum* (pĕr′ĭ·ŏs′-tē·*ŭ*m), from *peri — around,* and *osteon — bone.* This is the part from which new bone cells are formed. Let us see how a bone grows. Before birth, in the early embryo stage,

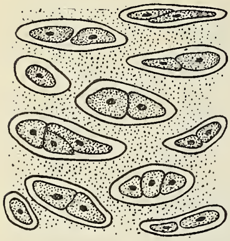


FIG. 10–5. Cartilage, the rubbery tissue of your ear and nose tip, is composed of cells such as those shown here. In the embryo, these cartilage cells may remain as cartilage or they may help to form true bone cells.

there are no bones. When they begin to form, they are not really bone at all; they are made of cartilage, the flexible, rubbery stuff of which your ears and the end of your nose are composed. [See Fig. 10–5.] Later, if the food absorbed by the embryo includes a sufficient amount of calcium and of *vitamins* C and D, true bone cells will begin to form in the cartilage. [See Fig. 10–6.]

FIG. 10–6. A bone begins its existence by the formation of a few bone cells among cartilage cells. These cells take in calcium and vitamins C and D from the blood to make walls. Cartilage cells are absorbed, the walls join, and the bone takes shape.

These new bone cells are somewhat like the first ice crystals forming in water which is beginning to freeze. A hard substance, mostly calcium phosphate, begins to form around each new cell. As more of this new substance is deposited, the bone takes shape. It gradually lengthens and widens, growing as do the other parts of the body. It is quite remarkable that, in a baby, corresponding bones in the arms and legs, in both sides of the head, the ribs and the spinal column grow at the same rate. The mother certainly cannot guide this growth. It seems possible that one leg or one arm might grow longer than the other. But such things rarely happen. There is a balance in the growth of the bones that is truly amazing. And the result is that when the baby

is born, the right arm is similar to the left arm. So it is with the legs. And the left and right sides of the head and of the body, both outside and inside, have grown also at the same rate.

208. **What do we mean by rickets?** If there is not sufficient calcium and vitamin *D* in a child's diet, and if the child does not get enough sunshine, weak and deformed bones develop. This condition is called *rickets.* There is no reason today for any child to have rickets. Science has given us the means to stamp out this disease.

*209. **What are fontanels?** The bones of the body are only partly developed at birth. There are several spaces in the skull where the bones have not yet touched each other. Between them are soft spots called *fontanels* (fŏn'tȧ·nĕlz'). It is true that one could quite easily push a finger down into the brain cavity through the fontanel at the rear of the top of the head of a young baby. Babies should not, therefore, be allowed to lie always on the same side when they sleep. The head could rather easily be pressed out of shape. The skull bones reach their full size early in life, perhaps when the child is six or seven years of age. A human being, however, does not get his or her full bodily growth until about the age of twenty years. This means that the bones of the body, other than those of the skull, have gradually and equally grown to the adult size through these years.

210. **How does the pituitary gland help to make normal bones?** Even if the food eaten contains good materials out of which to make strong bones, something else is necessary. There is a small gland on the underside of the brain called the *pituitary* gland, which we now know is very important in bone development. This little gland, about the size of a pea seed, passes off into the blood a substance which helps to regulate the size and daily growth of the bones. If by chance there is not enough of this substance secreted to produce normal development, then a dwarf is produced. Too much of this substance produces a giant.

211. How can we show that bones contain mineral matter? That bones have mineral matter can be shown by burning a bone as completely as possible. Mineral matter does not burn. The ashes that are finally left represent the mineral matter of the bone. The mineral matter of a bone can be dissolved by leaving the bone several days in dilute hydrochloric acid. When taken out, the bone should be as flexible as rubber, and, if it is long enough, it can even be tied into a knot. [See Fig. 10–7.]

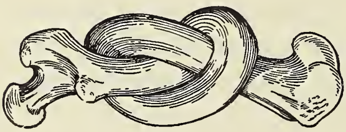


FIG. 10–7. If a bone is left in a weak hydrochloric-acid solution for a few days, the mineral matter will be dissolved. The bone will then be flexible, like rubber, and can be tied in a knot, as this one was.

212. How can growing bones be trained? Growing bones are less brittle than are older bones that have stopped growing. This is because the younger bones have not yet deposited much calcium phosphate or mineral matter. Since young bones are much more flexible than are old bones, they are not so easily broken. They can also be trained so that an individual, later in life, may have good posture without effort.

The erect carriage of the officer who went to West Point or to Annapolis is an example of what *can* be done with growing bones by well-trained muscles. [See Fig. 10–8.] The boy or girl who lets the shoulders fall forward in a slump over his or her books or who stands in a limp or lifeless way, is going to regret the results some day. Such a person is certainly going to be round-shouldered and to a certain degree unattractive in appearance. The cramping of the lungs also may be the remote cause of disease later in life. Later in this chapter practical suggestions will be made for attaining the habit of good posture.

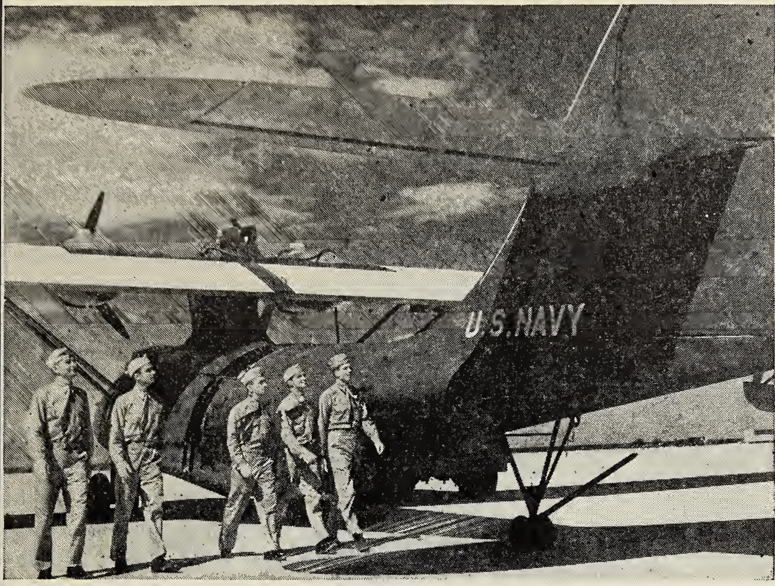


FIG. 10–8. Good posture, which comes as a result of much careful training, is an asset. Once learned, it becomes natural at all times. Notice that these naval aviation students carry themselves well even when they are off duty. (*Official U. S. Navy Photograph*)

213. Crowding twenty-six bones into a shoe. Many careless persons sacrifice their feet to a slavish following of style. When the human foot with its 26 bones is crowded into a shoe too narrow or too short or with too high a heel, not only are corns likely to develop on the surface of the foot, but the bones of the foot are likely to be bent and distorted. [See Fig. 10–9.] The joint at the base of the big toe may become enlarged and form what is known as a *bunion*. Or one or both of the bony arches of the foot may be broken down, causing much suffering and discomfort to the victim. Why be so foolish?

214. What should be done for a person with a broken bone? No bone of the human skeleton will break without unusual pressure. Such severe pressure is likely to injure muscles and other tissues, as well as the bone. There are

FIG. 10–9. It may surprise you to learn that there are 26 bones in the human foot. Each of these bones must work without unnatural friction, if it is to do its part in supporting the body. None of them can work properly if they are crowded into a poorly fitting shoe. Shoes that are too narrow or too short produce such unfortunate results as bunions, corns, and weak arches. (*Courtesy General Electric X-Ray Corp.*)

two kinds of breaks that should be considered. The *simple fracture* where the broken ends of the bone are still close together, and the *compound fracture* where the broken end of one bone has been forced through to the surface of the body with much *laceration* and injury to the surrounding tissues.

The first problem of the physician is to set the broken bone, by bringing the broken ends together and then applying a support that will be rigid. This result is usually obtained by putting the limb in a plaster cast. The doctor cannot heal the broken bone. All that he can do is to make sure that everything is in the right position. Then nature begins the miracle of healing, making new cells, depositing new bone, and repairing the break, until after a few weeks the bones are usually completely united.

215. How do bones and muscles work together? Every part of the human body except the vestigial organs has a purpose. Co-operating parts make possible bodily functions.

Bones, muscles, nerves, and ligaments working together produce movements and physical activity, without which we would be unable to live successful lives.

216. How does the dredge work? Have you ever joined a group of bystanders watching a great steam dredge? Have you seen the dredge scoop up a ton or two of earth, then swing it up through the air and down over the waiting truck, into which the load crashed when the engineer pulled a lever? The dredge seems to work by unseen power. However, the frequent hiss of escaping steam back in the control house tells the kind of power used. But steam alone could not do this work. There must be machinery to use this power; long arms and rods and cables, skillfully built to deliver this energy where it will do the kind of work required.

217. Does the body resemble the dredge? The human body may not seem to resemble this dredge at all; yet in the way in which the body works, it is like the dredge. If the body is to move or change position or do work, it must have parts where force can be applied. It must also have parts by means of which this power can do work.

218. How does the human arm work? Your arm, for instance, contains parts where force is produced and parts where muscular effort accomplishes something. The long bones serve as levers upon which the muscles may act. Suppose that you lift a pail of ashes from the floor, carry it out, and empty the ashes into the ash can. The force you used was not steam, but *physical energy*. This energy was produced in your muscles by the oxidizing of food or of *protoplasm*. How did this energy do the work? It caused muscles to contract, thereby pulling on bones and changing their positions. Instead of moving steel beams and cables, living tissues of the body were the machinery used. The actions and the work performed are quite similar, even though the dredge is a thousand times more powerful than you are.

219. How is a muscle constructed? If you examine a muscle, you can see for yourself how it is constructed. The

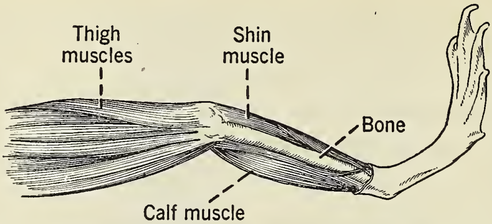


FIG. 10–10. By removing the skin from the leg of a frog, one can see the muscles.

hind leg of a freshly killed frog will be excellent for this purpose. [See Fig. 10–10.] Below the knee joint you can see a large, plump muscle. This is the *calf muscle* of the frog, very much like your own calf muscle. You will find a thin skin, or membrane, over it. By gently pulling, you can easily separate this muscle, for most of its length, from the bone. You can feel how soft it is. Notice where the two ends are attached to the bone. Each end of the spindle-shaped muscle is narrow and ends in a white, tough cord called a *tendon.* A tendon is almost as strong as steel of the same size. Let us cut across the muscle to see what it is like on the inside. Now in the cross section, you can see the cut ends of the fibers of the muscles. It looks much as though a saw had cut down through a bundle of sticks. If you could separate

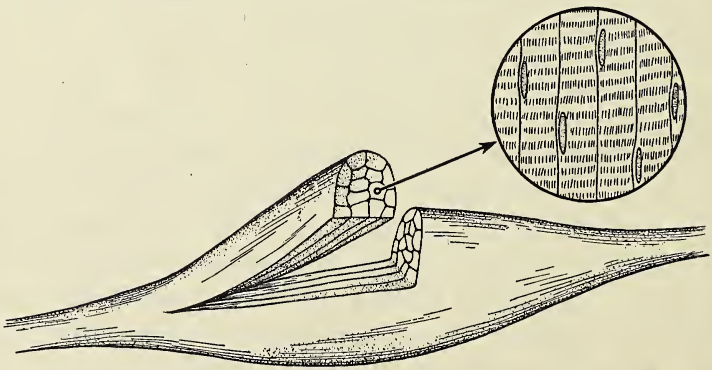


FIG. 10–11. A muscle is a soft organ, usually spindle-shaped, and composed of many fibers bound together. Each end of such a muscle terminates in a strong tendon by means of which the muscle is attached to a bone. The insert shows the muscle cells in a tiny spot.

ach of these fibers which you see, into the smallest parts hat compose it, you would find, by use of the microscope, hat a muscle, like all other parts of the body, is made up of iny cells. [See Fig. 10–11.]

220. What are voluntary muscles? A muscle like the alf muscle of the frog or of man, works usually under concious orders from the will. Such a muscle is called a *voluntary* muscle.

You have all seen a puppet show. Perhaps you have even nade puppets yourself. You know that the arms and legs f the puppets are controlled by strings. The bones of our odies are much like puppets. [See Fig. 10–12.] They canot move at all, but they can be moved by muscles attached o tendons. The muscle which moves a bone is firmly atached by a tendon to an immovable bone at one end. At he opposite end the muscle ends in another tendon. This endon is fastened to the bone which is to be moved. When he muscle contracts and becomes shorter, it "pulls the tring" and moves the bone. Just as the operator of a pupet controls its movements by pulling strings, so the mind, a naster operator, controls the movements of the body by directing the voluntary muscles to contract and to pull the trings which move the bones.

221. What are involuntary muscles? There is another ind of muscle in our bodies which works without mental rders. It is called an *involuntary* muscle. Such muscles nclude those which produce the beating of the heart, those vhich cause the eyelids to wink (actually both voluntary nd involuntary), those which push the food downward nto the stomach in swallowing, and those which cause the novements of the walls of the stomach and of the intestines. here are other involuntary muscles in the body.

222. How does a muscle work? A muscle works by conracting, or shortening, its fibers. Let us go back again to he frog mentioned earlier, and study the other calf muscle s yet unexamined. Carefully dissect this leg to free the calf

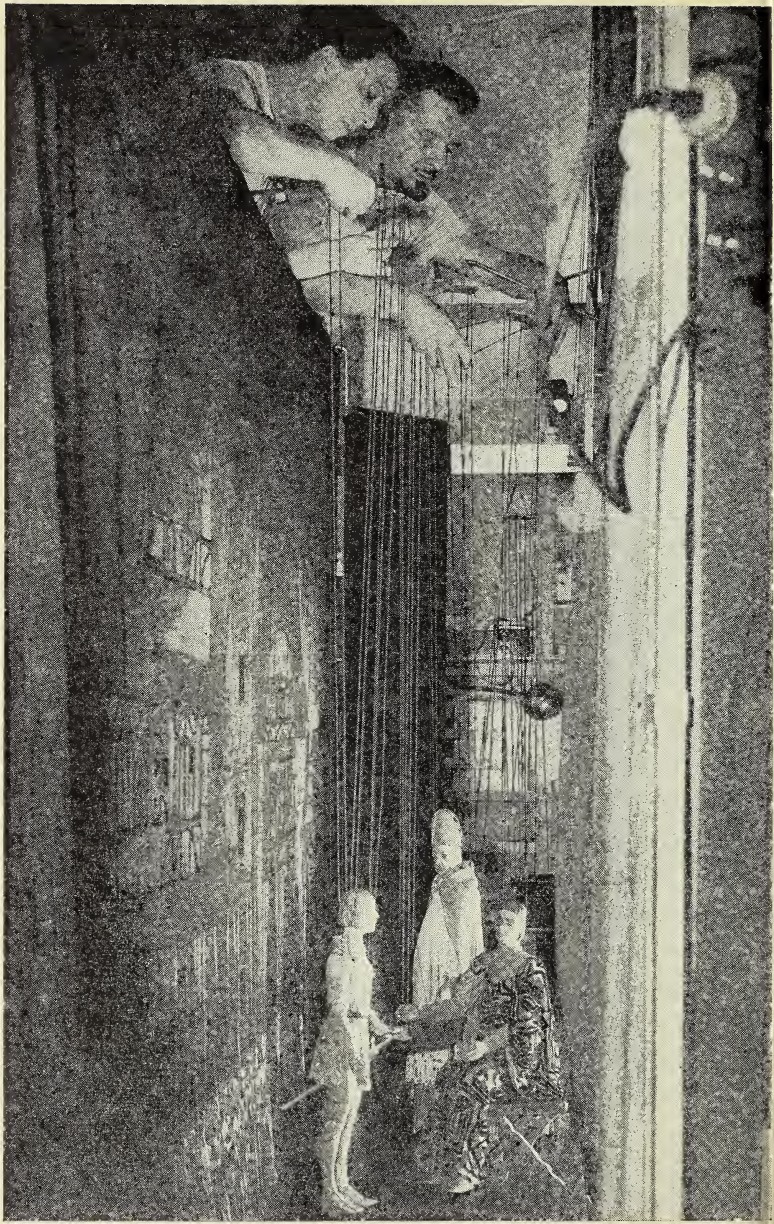
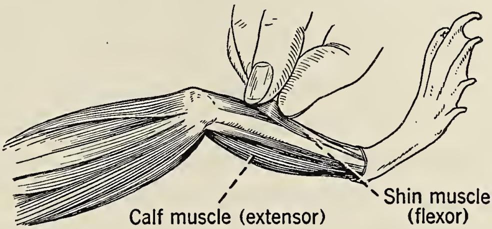


FIG. 10–12. Puppets are controlled by strings. Our bones are like puppets; the muscles and tendons are the strings. (*Frink from Monkmeyer*)

ıuscle, for most of its length, from the bone. Leave the ends f the muscle attached. Now hold the frog's head downward vith this leg in the air. Shorten the calf muscle by pinching t with your thumb and finger. What effect does such forced ontraction of this muscle have on the foot? Now dissect out ıe shin muscle – the one in front of the shinbone – freeing t from this bone for most of its length. Pinch, or shorten, his shin muscle. You will see that the foot is drawn up, or ontracted. [See Fig. 10–13.]

Fig. 10–13. Short-ning the shin muscle, flexor muscle, pulls p the foot.



223. What are extensor and flexor muscles? A muscle vhich extends an appendage is called an *extensor* muscle. muscle which bends an arm, leg, or other appendage is alled a *flexor* muscle. Is the calf muscle an extensor or a lexor for the foot? Which kind of muscle is the shin muscle?

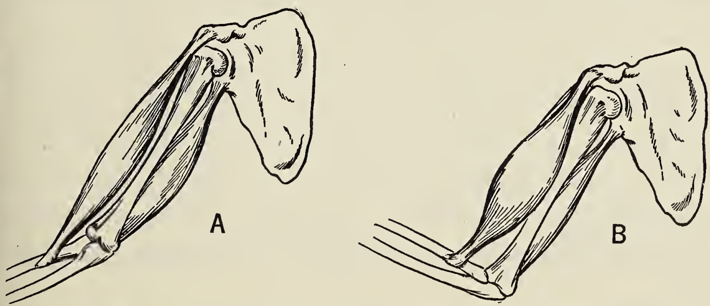


Fig. 10–14. In A, the arm has been extended by the triceps, which s an extensor muscle, on the lower side. In B, the lower arm has been oulled closer to the body by the contraction of the biceps, on the upper ide. What kind of muscle is the biceps?

Apply this to your own arm. Hold your left hand around the upper part of your right arm. Straighten your right arm, then flex it. Do this several times until you are sure which muscle in your upper arm is the extensor for the lower arm, and which is the flexor. You can tell by remembering that a muscle becomes harder when it contracts and is doing work. The flexor of your arm is called the *biceps* (bī′sěps) and the extensor is called the *triceps* (trī′sěps). [See Fig. 10–14.]

224. How do extensor and flexor muscles supplement each other? The large voluntary muscles are arranged in pairs, one being the flexor and the other the extensor. They are designed to *supplement* each other — that is, each supplies what the other lacks. For instance, the pitcher of a baseball nine uses a flexor muscle in order to draw his pitching arm into position for the throw. Then he uses his extensor muscles when he straightens his arm in the act of pitching. It is fortunate, when a person leans down to pick something from the floor, using the flexor muscles of the waist, that he has also, in his back, extensor muscles by means of which he can straighten up again. Thus flexor and extensor muscles of the same kind supplement each other.

225. Can muscles work without blood and nerves? There are approximately 800 muscles in the body. Each of these muscles is supplied with blood vessels and nerves, without which they would be powerless. Food and oxygen are brought to the muscles by the blood stream. Wastes are also carried away from the muscles by the blood. Even when food and oxygen are present, the living muscle cannot work, that is, contract, unless an impulse to do so comes in from its nerve.

***226. How can a nerve impulse stimulate a muscle?** By looking at the frog's leg, you can easily see the white nerve extending downward from the thigh and dividing just above the knee. [See Fig. 10–15.] One division goes to the calf

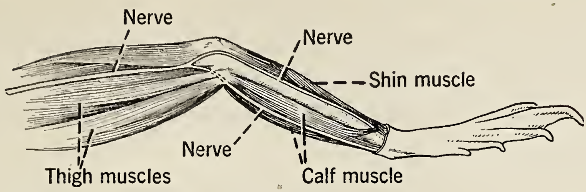


FIG. 10–15. Note the nerves reaching the muscles of the leg.

nuscle and the other goes to the shin muscle. What hap- pens when a nerve impulse comes to a muscle can be shown n a freshly killed frog by stimulating with electricity or acid he nerve of the calf muscle. You will notice the sudden ction of this muscle.

227. **What is fatigue?** Everyone knows that after work- ng a while a person is likely to become tired or fatigued. ust why does a person get tired? This is an interesting ques- ion which science can answer. Fatigue from muscular ac- ion seems to be due to the accumulation of a substance called *actic acid* in the muscles. When the lactic acid is removed y means of sleep, rest, or massage, the person no longer feels ired.

228. **What foods do muscles need for growth and re- pair?** It should be remembered that the blood carries to the muscles only such food as the individual eats. If the per- son is wise, he will provide his muscles with the right kind of building material for growth and repair. A diet contain- ing meat, fish, eggs, milk, wheat, nuts, peas, or beans will furnish many kinds of protein food out of which to make and repair muscle cells. The diet should also include essential vitamins and mineral substances, many of which are obtained from fruits.

229. **What foods do muscles need for action?** While proteins under certain conditions can be oxidized to furnish energy, fats and carbohydrates (foods which furnish heat — for example, sugar and starch) are much better for this pur-

pose. Sugar in the form of chocolate is a food quickly oxidized, and it has been used with good results by soldiers, explorers, and athletes. Bread, butter, sugar, potato, cream, cheese, vegetables, and peanut butter are well-known energy-producing foods.

230. Should muscles be given stimulants? It is true that athletes like boxers, wrestlers, and others may use stimulants like strychnine (strĭk′nĭn) in emergencies. However, boys and girls will only harm their growing muscles by drinking coffee, containing *caffeine* (kăf′ē·ĭn); by drinking tea, containing caffeine, *tannin* and *theine* (thē′ēn); by smoking cigarettes, containing *nicotine* (nĭk′ō·tēn) and *acrolein* (ȧ·krō′lē·ĭn); or by drinking alcohol in any form. Many experiments show that the muscular protoplasm of young persons is injuriously affected by the use of stimulants or narcotics, particularly nicotine and alcohol.

231. Should muscles be exercised? There is no doubt that our muscular systems are for use. Therefore muscle activity is normal. Young persons, particularly girls, often do not get sufficient exercise. They are not necessarily lazy because they would rather read than play. However, the

FIG. 10–16. Pleasurable exercise, in moderation, helps to increase poise, bodily health, and zest for living. Athletic accomplishments help to make a person more social-minded. And it is not necessary to win a contest to enjoy these benefits. (*Courtesy Evanston Township High School*)

body benefits in two ways from enjoyable exercise. [See Fig. 10–16.] First, the organs of the body are kept active, and the blood and lymph circulate more freely, appetite and digestion are benefited, muscles are strengthened, and brain and nerves are kept in good condition. All this means better bodily health. Second, the person who follows the modern tendency to get plenty of recreation and learns to play a good game of tennis, baseball, badminton, handball, or golf, or to swim, ski, or skate well, will usually not develop an *inferiority complex.* He avoids it because he has accomplishments which will always be social assets and which will increase his self-confidence. Exercise should be for the joy of it and always out of doors if possible.

Exercise can be overdone. There are always some foolish persons in this world who seem to take delight in being able to boast of having played half a dozen successive sets of tennis or thirty-six holes of golf. " Moderation in all things " is a good motto for everyone. Excesses must be paid for sometime, and they are likely to be paid for by a shortened life.

232. What muscle injuries should be avoided? (*a*) If a boy or a girl is going to take part in athletics, a physical examination should be given by a competent physician. If the examination shows a weak heart or any other physical condition which would be overtaxed by athletic activities, such strain may be avoided.

b) Every adolescent who engages in games or contests should train for such events. But a contestant should not overdo either in such preparation or in actual competition. In training, the loss of weight, sleep, appetite, or zest is an indication that he is going stale, and should take a complete rest for a while.

c) At the beginning of the season there may be muscle strain. This consists of the actual breaking of some of the fibers of a muscle or of its covering or of its tendon attachment. Such an injury may be very slight, or it may be a

pulled muscle, serious enough to prevent participation in athletics for weeks. Strains usually need rest and massage.

d) A severe blow may bruise a muscle, particularly if the muscle is flexed at the time. Such an injury to the larger thigh muscle is called a "Charley horse." A bruised muscle is very painful, and the flesh around it is usually discolored on account of the blood from ruptured blood vessels, which collects in the muscle.

e) Excessive strain sometimes ruptures part of the tendon of the muscle or its attachment to the bone, such as the heel. Such an injury is called a *pulled tendon.* This is very serious, and requires rest, massage, and heat. Care must be exercised when the muscle is first used again.

233. How are muscles related to good posture? Earlier in this chapter, emphasis was placed on the importance of training the skeleton while a person is young and his bones are pliable. Such training makes good posture a permanent habit because the bones develop into the right position. Good posture throughout life depends to a large measure upon the effect of training the skeleton. This would be impossible, however, without training the associated muscles, since movement depends primarily upon the muscular system.

234. How can good posture be attained? In countries where it is common practice to carry burdens on the head, even peasant women have gained a carriage, or bearing, which might be called regal. [See Fig. 10–17.] So it is very good practice to walk frequently with a book balanced on one's head. Another practice is to thrust the arms up and over the head, then forward, pushing against an imaginary or a real wall. Start each day with this exercise. Bend forward, not from the waist but always from the hips, *keeping the trunk straight.* Setting-up exercises are excellent for most persons.

235. How important is the mind in producing good or bad posture? Muscles are not self-acting, and good posture

FIG. 10–17. This Mexican woman is carrying her large load of hats and baskets to market. Carrying burdens on the head is common in many parts of the world. A person who does carry large or heavy articles on his head acquires balance for this by an erect posture. Try balancing a book on your head while you walk around the room; do not steady the book with your hand. Notice how straight your back is when you have succeeded in balancing the book. (*Courtesy Mexican Government Railway System*)

usually does not come naturally to us. Voluntary muscles act only upon orders from the mind. Therefore, good or bad posture is the direct result of the kind of thoughts a person has been thinking for a long time. Traits such as laziness and shiftlessness, as well as feelings of inferiority and loss of self-respect, are frequently the cause of many of the examples of poor posture we see so often in persons about us. Likewise, good posture is partly the result of self-respect, ambition, and self-discipline.

236. When should good posture be acquired? It is an important thing to discipline the growing body, not by hurting it, as do some fanatical savages, but by forming correct posture habits early in life. Realize that you yourself, with your *mind in control*, can in a large measure be guide and counselor to your own body. Practice setting-up exercises at home, at school, and at camp. Desire good posture; think good posture. Then it will be a satisfaction to you as you

see the body obeying. Once really acquired, your habit of good posture will probably stay with you for the rest of your life.

QUESTIONS

1. How many bones are there in the skull? in the spine? in the arm? in the hand? in the leg and foot? How many bones are there in each shoulder and each hip? How many ribs?
2. Is it true that at an early stage of the embryo, the human body is boneless?
3. How is the brain of a vertebrate protected?
4. What are the parts of a living bone?
5. What kind of cells precede the formation of bone?
6. What special substance must food contain in order to build good bones?
7. How can rickets be avoided?
8. What small gland helps to regulate the size of the skeleton?
9. How can a bone be tied in a knot?
10. Can you name and locate five kinds of joints? What are they?
11. How can good posture be secured and maintained?
12. Why is good posture worth having?
13. What defects of the foot are likely to follow the use of shoes that are not correct as to size and fit?
14. Can you name ways in which your arm resembles the arm of a dredge? What are they?
15. What are the parts of a complete muscle?
16. What is a tendon?
17. Can you distinguish between a voluntary and an involuntary muscle?
18. What is the difference between a flexor and an extensor muscle? Name an example of each and locate them in your own body.
19. Locate and give the use of the biceps and the triceps muscles.
20. How many muscles are there in the human body?
21. Why must a muscle be supplied with a nerve?

22. What causes physical fatigue?

23. What foods should be eaten for muscular growth and repair?

24. What foods should be eaten for release of energy in muscles?

Some things for you to do

1. Get a long bone in the market and examine all its parts.

2. Soak a leg bone of a bird in dilute hydrochloric acid until it is soft and flexible. Then try to tie it in a knot. Vinegar will also produce this result, but it will take longer.

3. Read all you can about the pituitary gland and its functions, then write a report on this subject.

4. With the assistance of some older person, carefully measure yourself and record your physical measurements. Copy the following form and use it for your record. Mount the form on a sheet of cardboard, or paste it in a notebook for safekeeping.

	Junior High School				Senior High School					
Grade	8		9		10		11		12	
	S.	F.	S.	F.	S.	F.	S.	F.	S.	F.
Height (without shoes)										
Neck										
Chest (after exhaling)										
Chest (after inhaling)										
Waist (girth)										
Biceps (relaxed)										
Biceps (contracted)										
Calf										

Keep this chart, and twice a year during your years in the high school, in September and in February, take and record your measurements.

5. Try the experiment of causing muscular movements by stimulating the nerves of the leg of a freshly anesthetized frog, by using the current from a dry cell. You should do this under the direction of your teacher.

THINK ABOUT THESE!

1. How are your fingernails like the horns of the cow and the feathers on a canary bird?

2. Do you believe that there are more than 500,000 pores in the palms of your two hands?

3. How many kinds of nerves are there in your skin?

4. How does the skin help to keep the temperature of the healthy body almost constant at 98.6 degrees, day and night, summer and winter?

WORDS FOR THIS CHAPTER

Epidermis. The outer layer of skin.
Modified. To be changed or altered.
Whorl (hwûrl). As used here, the curving lines found on the tips of fingers.
Dermis. The second layer of skin, below the epidermis.
Eliminate. To pass off.
Capillaries. The smallest of the blood vessels.
Co-ordinated. Made to work together; unified.
Ultraviolet rays. Rays shorter than the shortest light rays. They are invisible to the human eye.

CHAPTER 11 ———————— UNIT 5

Why Do We Have Skin?

237. Do most plants and animals have a protective outer layer? Look at an apple. What part of the apple is on the outside? What part of an orange is on the outside? What part of a nut? Most animals have a protective layer on the outside, just as these fruits have. Fishes have a layer of skin and a layer of scales; birds have a layer of skin and a layer of feathers; and mammals have both skin and hair. Perhaps you have never thought of your skin as such a protective organ.

238. What is the epidermis? When you have been exposed to strong sunlight for some time, you are likely to have a sunburn. Later, a very thin outer layer of skin, killed by the heat of the sun, begins to peel off. This thin layer is only one of the many layers which make up the outer skin. All of these layers taken together constitute the *epidermis.* The outer cells of the epidermis are constantly dying, whether or not you are sunburned, and it is these dead layers that are rubbed off, a little at a time, every day. You can prove this by washing your arm with soap and water. After drying your arm, rub it several times back and forth with your free

hand. Rolls of little particles will presently appear under your hand. These are made of dead skin rubbed off by the friction. The principal use of the epidermis is to protect the inner skin and the muscles and other delicate parts underneath. Where there is much pressure against the epidermis, as from shoes that do not fit well, extra layers of epidermis may be formed. Such growth may result in callous spots, which, if the pressure continues, may develop into corns.

239. How is the epidermis modified in different animals? The epidermis may be *modified* in different animals. Thus scales of fish or snakes, feathers and bills of birds, horns of deer, claws of cats, and hair and nails of human beings are all epidermal in character, each growing from the dermis beneath. [See Fig. 11–1.]

FIG. 11–1. Skin may be altered to form very different structures. The scales of the fish, the antlers and hair of the stag, the complete feather of the bird, and the hair of man are all examples of modified skin.

240. How valuable are fingerprints? The *whorls* and lines in the skin of the tips of the fingers have been found to be peculiar to each individual. Thus fingerprints are generally considered to be about the most valuable means of identification. Fingerprinting is not only valuable in detecting criminals. It is advantageous in protecting bank depositors and in making identification sure and scientific. [See Fig. 11–2.]

241. What is the dermis? Underneath the epidermis is a thicker layer of skin called the *dermis.* In this region are to be found blood vessels, nerves, sweat glands, oil glands,

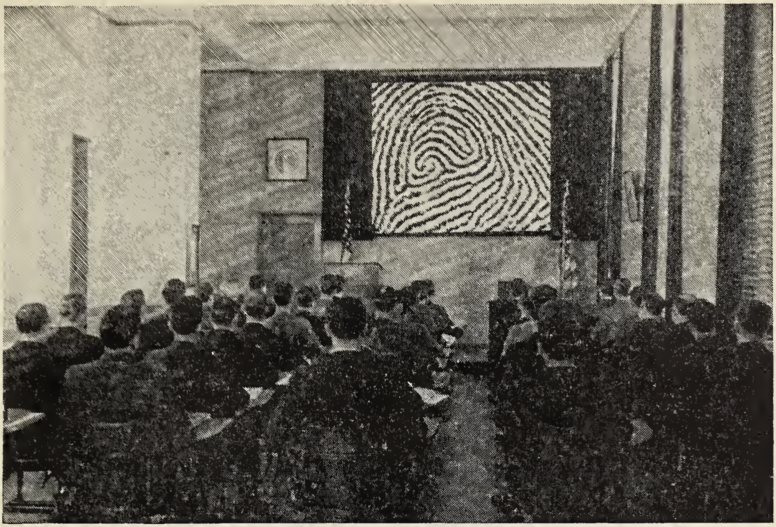
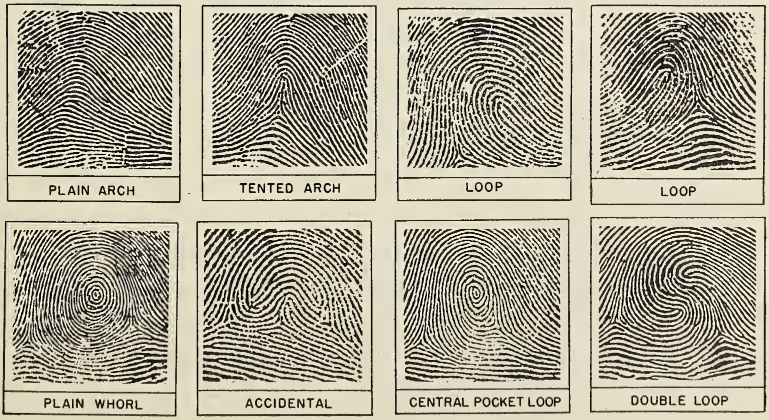


FIG. 11–2. Two famous scientists, Purkinje in 1823 and later Galton, pioneered in the use of fingerprints for identification. Bertillon devised the system now used throughout the world. The U. S. Department of Justice, through its Federal Bureau of Investigation, has the world's largest collection of fingerprints — over 5,500,000 records, and the number is constantly increasing. In the picture above, members of the FBI study greatly enlarged fingerprints projected on a screen. No two fingerprints are exactly alike; they vary in pattern of arches, whorls, and loops. (*Courtesy Federal Bureau of Investigation, U. S. Department of Justice*)



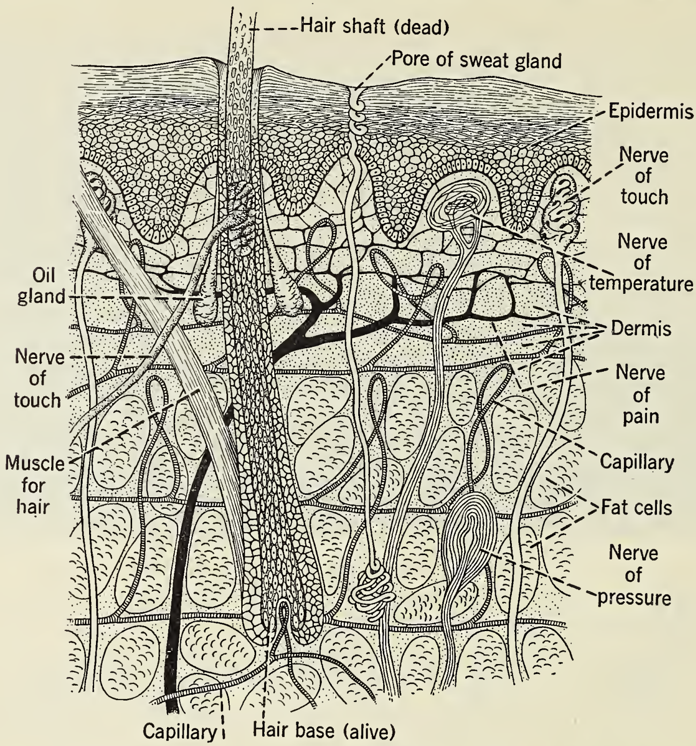


FIG. 11–3. This cross-sectional view of the human skin shows its complicated structure. The white nerve of pain is black for contrast.

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and roots of hairs. Most of the dermis consists of tough, strong connective tissue. The sweat glands are tiny, coiled tubes extending up through the dermis and epidermis. [See Fig. 11–3.] There are many of these sweat glands in the body. Each sweat gland has an opening called a *pore,* through which perspiration is constantly being given off from the body. There are about 3,000 pores in one square inch of the palm of the hand. Perspiration usually is invisible. This excretion is called *insensible perspiration.* When the body is warmer, perspiration comes out in droplets. This is called *sensible perspiration.* The body *eliminates* from one to two pints of sweat each day.

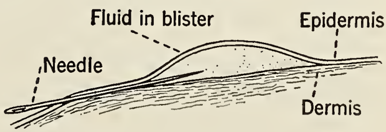
***242. What kinds of nerves are in the skin?** The nerves in the dermis are of several kinds: (*a*) nerves sensitive to touch; (*b*) nerves sensitive to pain; (*c*) nerves sensitive to temperature; and (*d*) nerves sensitive to pressure. Nerves of touch are so close together that it is difficult to find any spot on the surface of the body where a person would have no sensation of touch. Draw a nail file very lightly across the skin of your hand. You feel touch, or possibly heat or cold, but not pressure. If the file is pressed against the skin, the sensation is more than touch; it is pressure. The nerves of pressure, which are deeper, have now been stimulated.

If the point of the nail file or the point of a pin is pushed into the skin, then in addition to pressure there is pain. Certain pain nerves have been stimulated.

The way in which these stimulations of nerves become sensations or feelings will be taken up later in Chapter 16.

243. What is a blister? If the skin undergoes a harsh rubbing, such as the rubbing of the handle of a shovel against the hands of a person not used to shoveling, a blister is likely to occur. In this case, the epidermis has separated from the dermis, and the space between them has been filled with a colorless fluid. If the fluid can be extracted by running a sterilized needle under the adjoining epidermis into the space, without admitting air, the loosened epidermis usually adheres again to the dermis. If exposed to the air, however,

Fig. 11–4. Fluid from a blister can usually be extracted by carefully running a needle under the epidermis without admitting much air.



healing is postponed and there is likely to be more pain because some nerves in the raw dermis are exposed. [See Fig. 11–4.]

244. Can the skin of animals be changed to leather? The skin of many animals can be changed into leather by a

series of chemical processes called *tanning*. Skin in the form of leather becomes very durable and is used by man for many purposes, such as straps, saddles, harnesses, shoes, and belts for machinery.

245. The skin is the first line of defense against bacteria. Skin, if unbroken, forms an almost perfect defense against the entrance of bacteria into the body. The skin is also very elastic. This allows for increase in size of the body as in normal growth. However, skin does not so easily accommodate itself to loss in weight and decrease of surface. This is one of the main causes of wrinkles in the skin of old persons.

246. How does the skin, working with the nerves, regulate the body temperature? Perhaps the most remarkable function of the skin is the regulation of body temperature. All through the dermis are tiny *capillaries*. These are elastic, and, by swelling, can hold much more blood for a time than the usual amount. Strong feeling such as joy or embarrassment may send excess blood into the capillaries of the face and cause the face to flush. Likewise, fear or shock may cause the blood to leave the capillaries of the face, and we say "How pale she is!" The shock may be severe enough to cause the blood to leave the brain. In that case the person usually faints.

The human body is organized to have a normal temperature of about 98.6° F. If you exercise or are excited, the internal temperature of your body may greatly exceed this for a time. Some of this heat passes off from the lungs in the exhaled air. But most of the excess body heat is quickly lost by another means. The nerves lying close to the blood vessels of the skin cause these capillaries to expand. They now receive more blood, which tends to lose heat as it now passes near the surface of the body. Other nerves stimulate the sweat glands, and perspiration now pours out on the skin. As this liquid, mostly water, evaporates, the temperature of the skin, and thereby of the blood passing through it, is further lowered. [See Fig. 11–5.]

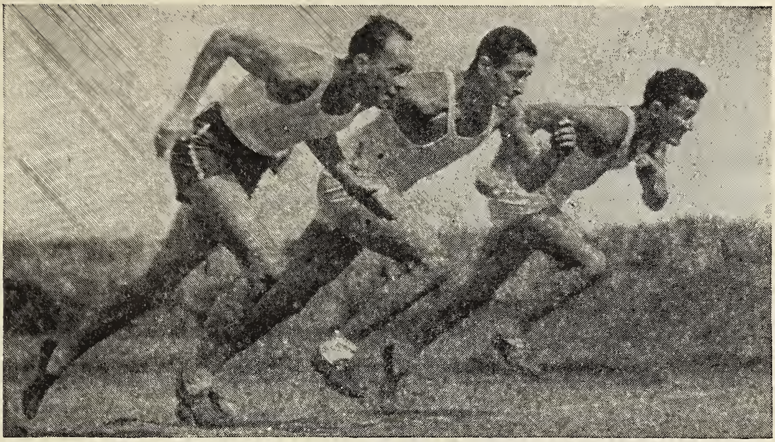


FIG. 11–5. The human body during exercise produces considerable heat. Perspiration passes off from the skin, helping to lower body temperature. (*Ewing Galloway*)

This *co-ordinated* activity of nerves, capillaries, and skin is as automatic as the action of the thermostat in a furnace, in an oil burner, or in an automobile. In fact, it *is* a sort of living thermostat.

It is fortunate that the skin and nerves act automatically, because there are a great many absent-minded individuals who would certainly forget to attend to the important matter of regulating the body temperature.

247. How is vitamin D formed in the skin? Whenever the skin is exposed to sunlight, a remarkable thing happens. The *ultraviolet* rays in the sunlight affect an oil in the skin, changing it to vitamin D. This is picked up by the blood and is very useful in the body in connection with the building of strong bones and teeth.

248. Is beauty only skin deep? A skin that is soft, that is free from pimples and other blemishes, and that has a healthy glow, is a desirable asset. But there are unfortunately many persons who act as though they believed that " beauty is only skin deep " and who use cosmetics lavishly in order to give the impression of facial perfection. The surest and safest

way of acquiring and keeping a good complexion is by aiming first at the good health of the entire body. A moderate amount of pleasurable exercise in the open air, thoughtful attention to the kind and amount of food eaten, sufficient sleep, and regular elimination from the bowels are all very important conditions for health. The attainment of a happy state of mind is important too.

Growing boys and girls, during their junior- and senior-high-school life, sometimes experience an outbreak of pimples on their faces. This seems to be connected in some way with the development of the body, and although it may be embarrassing to the victim, such a condition usually clears up if the rules of health are followed.

249. Why should one bathe? It may be surprising to learn that some persons who rarely bathe are not necessarily more likely to become ill on that account. Pores in a dirty skin will still open to allow perspiration to pass off. There are many savages in different parts of the world who never bathe throughout their lives.

Yet civilization is frequently judged by the amount of soap consumed. This is likely to be true, since dirt is offensive to refined persons. It is also true that dirt may carry disease germs if the skin is broken. No self-respecting person will tolerate unpleasant odors from his own body.

Even though the purpose of bathing is primarily to remove dirt from the skin, there is considerable health value in taking a daily cool or cold shower. The skin thus becomes accustomed to changes in temperature. The arteries in the skin contract during the shower and then expand during the brisk rubbing with the towel, which should follow. A warm bath is even more cleansing than a cool bath, and is very relaxing. It is best taken at night.

A good rule to remember is not to bathe or swim within an hour after a meal, as blood needed in the stomach is brought to the skin. Also, there is danger of cramps.

Some persons' feet perspire in excessive amounts. Such

persons should bathe their feet often, use talcum powder on their feet or in their shoes, and be sure to change stockings daily.

250. How should the hair be cared for? The hair is not only an outgrowth from the skin; it is a kind of modified skin. Normally, hair is supplied with oil from the glands of the scalp. A common malady, however, is the formation of dandruff, which consists of scales of dried skin. This condition can usually be avoided by vigorous shampooing of the hair with a good neutral soap. Laundry soap has too much alkali in it for this purpose. If girls and boys would early form the habit of frequent shampooings of the hair, of daily massaging the scalp and hair with the fingers, and of brushing the scalp, there would be fewer bald persons or persons with scanty hair. Such massage or brushing aids the circulation of the blood through the scalp. Science has not yet determined why men are more prone to baldness than are women.

251. Should boys and girls care for their nails? Clean fingernails mark the person who is careful of his or her appearance. Many a person, careless in this respect, has been rejected when he would otherwise have obtained a position.

252. What are the uses of the hair and nails? You have learned that the hair and nails, if properly cared for, may help to produce an attractive appearance, or even beauty. The hair also affords considerable protection to the head, both against temperature changes and against injuries from blows or falls.

The nails are useful in picking up small objects such as pins, and they give firmness of grasp to the fingers. They also afford protection to the ends of the fingers.

QUESTIONS

1. What are the different layers of skin? What structures are found in each layer?
2. What is a sunburn?
3. What is a callous spot and how may this be related to shoes?
4. How many forms of modified skin in different animals can you name? What are these forms?
5. What is a sweat gland? What is the function of sweat glands? Are there many of them in the human body?
6. How can the courts use the formation of the skin on the finger tips for sure identification?
7. How many kinds of nerves are there in the skin?
8. What is a blister?
9. Why is skin an "almost perfect defense against the entrance of bacteria" into the body?
10. What is the cause of wrinkles in old persons?
11. What causes blushing?
12. What causes fainting?
13. How does the skin regulate body temperature?
14. What vitamin can be found in the skin? How is it formed?
15. What is the best procedure for obtaining a beautiful skin?
16. Why should one bathe?
17. What is the value of different kinds of baths?
18. What kind of treatment should be given to the hair?
19. Why should nails be kept clean?

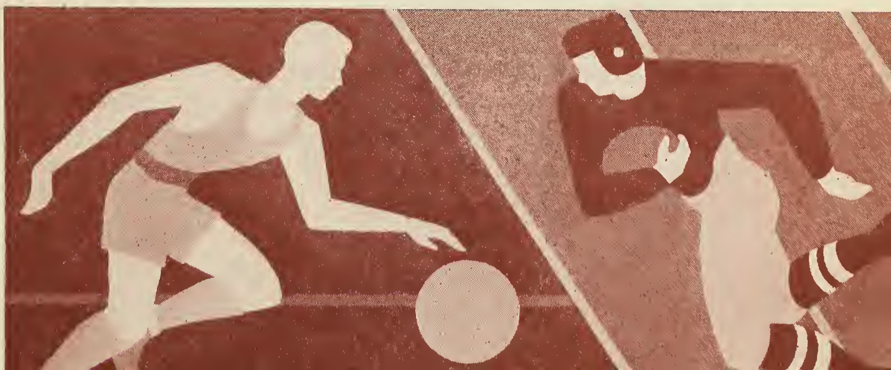
SOME THINGS FOR YOU TO DO

1. Use an ink pad and take your fingerprints by pressing the tips of your fingers with a light rolling pressure, taking one finger at a time. Compare your fingerprints with those of a friend.
2. If possible, visit the police headquarters of your city or village and note the method of fingerprinting practiced there.
3. Hold your hand for a minute or two against a glass surface, such as a window. Note the moisture which immediately forms as the result of the passing off of insensible perspiration.

Our Bodies Work Like Machines

We think of the body as a sort of machine with parts working together in harmony. In some ways, as you will find out in Unit 6, the body is superior to any machine. If a part is broken or cut, and the proper care is given to it, it is self-repairing. The body keeps a uniform temperature both summer and winter. It manufactures a liquid, blood, and pumps it through all the cells, so that they have equal opportunity to get food and air. It secretes substances capable of altering food so that it can be of service in the body. It also secretes hormones, which regulate normal growth.

Yet the human body is not so protected as the elephant or the alligator, is not so swift as the antelope, so agile as the monkey, so far-seeing as the bird, so keen-scented as the dog, or so tireless as the horse. Man's superiority lies in the development of two organs, the brain and the hand. Man should always be proud of his ability to think, and equally proud of his ability to use the most wonderful organic tool in



the world, the human hand. The ability to think and to create with the hands brings a definite responsibility for each of us to think and act so that the world will be a little happier and further advanced because we have lived there.

Think about these!

1. Did you know that white of egg is an excellent tissue-building food, but if injected into the blood without first being digested, it is a violent poison?
2. Could food be digested in a tin pail if you added the proper substances?
3. Can you explain how the same kind of food is changed into hair and eyes in one part of an animal's body and into muscles in another part of its body?
4. Has any scientist ever produced living forms?

Words for this chapter

Enzymes (ĕn′zīmz). Substances that cause chemical changes without themselves being altered.

Salivary (săl′ĭ·vĕr′ĭ) **glands.** Glands which secrete the fluid called *saliva.*

Saliva (s*ȧ*·lī′v*ȧ*). The fluid which discharges into the mouth. It aids in tasting, chewing, and swallowing, and in producing speech.

Lymph (lĭmf). The colorless fluid that surrounds the cells of the body.

Assimilated (*ă*·sĭm′ĭ·lāt′ĕd). Changed over into protoplasm.

Biochemist. A person well versed in the knowledge of the chemical actions that take place in the bodies of living things.

CHAPTER 12 ______________ UNIT 6

How Do Our Bodies Get Energy and Building Material from Food?

253. What is digestion? If you were to hold an apple in your hand for several hours, the apple would not be affected, except for being warm and perhaps softened. But if it had been chewed and swallowed, before long this same apple would have been so much changed that you could no longer recognize it at all. In fact, most of it would have been changed to a liquid. Certain substances would have acted upon it, altering it both as to physical appearance and as to chemical composition. This chemical changing of food so that it may be of use to the body is called *digestion*. Food is digested for two reasons. First, digested food can pass through membranes in the body. Second, food when digested is in a form where it can be used by the body as a fuel, or for growth and repair. [See Fig. 12–1.]

FIG. 12–1. Food is used for fuel — producing energy, and for assimilation — making protoplasm.

Some digestion takes place in the mouth, and more in the stomach, but the greater part of digestion takes place in the small intestine. Certain digestive fluids are poured out on the food in each of these three regions. These digestive fluids contain substances called *enzymes*, or ferments. An enzyme is a substance which changes the chemical composition of another substance without itself being altered.

There are at least ten different kinds of enzymes in the alimentary canal: one kind in the mouth, two kinds in the stomach, and the other kinds in the small intestine. Each enzyme acts only on certain kinds of *nutrients*, or nourishing substances.

254. What is the alimentary canal? As some of you know, a food tube called the *alimentary canal*, about as long as from corner to corner of the average classroom, extends through the trunk of the body. It begins with the mouth and, at the rear of the mouth, opens into the throat. From the throat, the *gullet* leads directly down into the stomach. The *stomach* is the largest part of the alimentary canal. A coiled

tube called the *small intestine,* extends downward from the stomach. The small intestine is about one inch in diameter, and twenty feet long. It winds and coils back and forth and finally connects with the *large intestine,* or *colon.* This intestine is from two to three inches wide, and is about five feet long. The large intestine extends from the lower part of the abdomen up nearly to the stomach, across to the left side, and then downward, until it terminates at the *anus.* [See Fig. 12–2.]

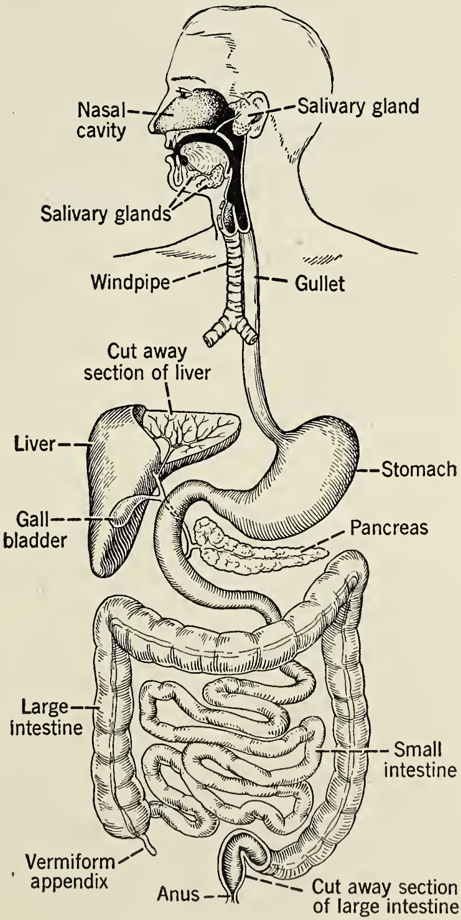


FIG. 12–2. The alimentary canal is about 26 feet long. It is widest in the stomach, although the large intestine is almost as wide in certain places. The food is squeezed through the alimentary canal by muscles in the walls. The food receives digestive juices from the salivary glands; from glands located in the walls of the stomach; from the liver, the pancreas, and the intestinal glands. Wastes from digestion of many foods pass down through the alimentary canal within 24 hours after being eaten.

255. What are the salivary glands? In the walls of the mouth there are three pairs of *salivary glands,* each of which produces and secretes *saliva* into the mouth through a duct. If you wipe dry the inside of one cheek, and look into your mouth in a mirror, you can see the saliva flowing from an opening just over the lower teeth on that side. This saliva comes from one of the largest pair of salivary glands, located just below and in front of the ear lobe (the external flap, or projection of membrane, below the ear). Another pair is under each jaw. The third pair lies underneath the tongue. Saliva is not only a valuable digestive fluid, but it moistens the mouth and the food, and enables the tongue to move freely. [See Fig. 12–3.]

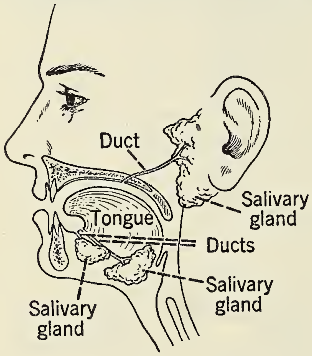


FIG. 12–3. From the three pairs of salivary glands, the average adult daily secretes about a quart of saliva, 95 per cent of which is water. Saliva not only helps to digest starchy foods; it is necessary in producing speech.

In addition to the salivary glands, there are four other kinds of digestive glands, which together with the alimentary canal, form the *digestive system.*

256. What happens to food in the mouth? Food, if it were consciously trying to avoid being bitten or crushed in the mouth, would have a difficult time doing this in the mouth of any intelligent person. The tongue constantly assists in the operation of moving the food around so that the teeth can cut and chew it. A gristmill usually has only two grinding stones. [See Fig. 12–4.] Between twenty-four and thirty-two teeth in the mouth bite and chew the food before

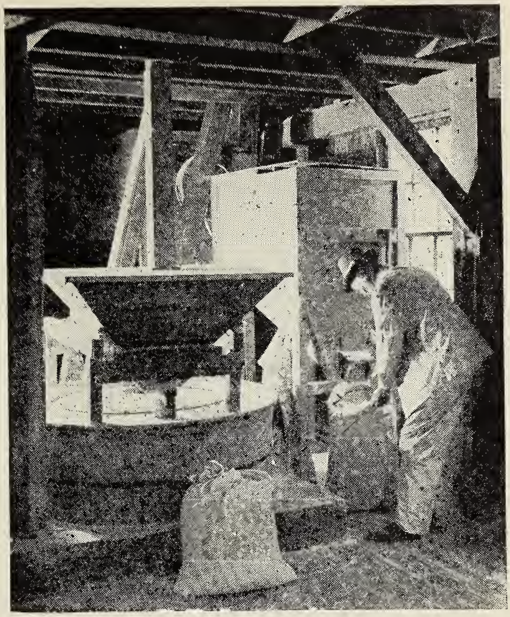


Fig. 12–4. A grist-mill has two large flat stones, one above the other, which revolve in opposite directions. Grain is supplied through an opening in the upper stone. This grain is first crushed and then ground to the desired fineness between the two millstones. (*Courtesy Pepperidge Farms — photo by Richard Averill Smith*)

it passes into the throat and stomach. Of course, unintelligent and careless persons may be willing to let food be swallowed with little or no chewing.

Chewing not only reduces the sizes of the food particles in the mouth, but it also mixes saliva with the food. This is necessary before extremely dry food can be swallowed. In addition, saliva actually changes the character of some of the foods. Digestion, therefore, begins in the mouth. A simple demonstration will prove this. Take a piece of dry cracker. Chew it as long as possible and note whether or not it becomes somewhat sweeter. It should. Saliva has a chemical action on starch. This is due to the presence of an enzyme called *ptyalin* (tī′ȧ·lĭn), which is present in the saliva.

257. How can an experiment show that starch is digested in the mouth? Prepare some starch paste. Add a little to some water in a test tube. Test this starch paste and water for the presence of sugar, by adding a few drops of

either Fehling solution or Benedict's solution. Gently heat the mixture. As the mixture becomes hotter, look for a greenish color, quickly changing to brown and then to brick red. This will mean that *sugar is present.* Now put some saliva into another test tube, and test this for the presence of sugar. To water and starch paste in a third test tube, add some saliva; shake and gently warm the contents to body temperature. Let it stand for thirty seconds; then test it for the presence of sugar. What do you conclude? Give your reasons for testing both the starch paste and the saliva for the presence of sugar. Why is it important to warm the contents of the third test tube?

258. What digestion takes place in the stomach? In the walls of the stomach are many tiny glands. Each gastric gland looks like a little bottle. [See Fig. 12–5.] Whenever

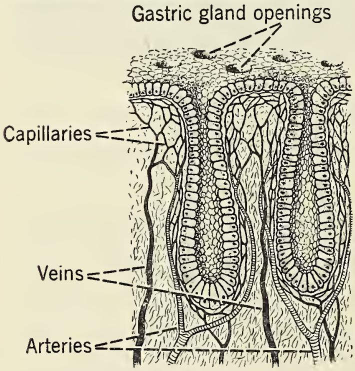


FIG. 12–5. Lining the wall of the stomach are thousands of small gastric glands; two are shown here in cross section, and five openings can be seen. Notice the blood vessels around the glands. Do you know why blood must be brought to the gastric glands?

there is any food in the stomach, drops of gastric juice keep coming out of each gland. Each drop is sour, because it has in it some hydrochloric acid. It also is made up of water and a digestive enzyme called *pepsin.* By experimenting, men have found that gastric juice will digest protein and some mineral substances.

259. What digestion takes place in the small intestine? Food, on leaving the stomach, is largely liquid, although it is only partially digested. Several glands open into the small intestine and pour new digestive juices on the food. The

pancreas secretes pancreatic fluid. From the *liver* comes the bile; and the *intestinal* glands, located in the wall of the intestine, pass off intestinal juice. The bile is important in the digestion of fats. Both the pancreatic fluid and the intestinal juice contain enzymes that will digest starch, sugar, and protein. An enzyme in the pancreatic fluid also will digest fat. Almost all of the digestion of our food takes place in the small intestine. The stomach acts as a temporary storehouse for food rather than as a digester of much of the food.

260. How does digested food get into the blood? Even after the food is digested, it is still inside the alimentary canal, and cannot be of use to the body until it can get out and be carried to the cells of the body. Some liquid, such as the rapidly moving blood, seems to be the only possible means of transportation. The blood in the walls of the alimentary canal is very close to the digested food. But it is enclosed within the walls of its own blood vessels, which are without entrances. How can the food be expected to get into the blood stream? Modern scientists do not yet know enough to answer the question completely. But it is known that all the digested nutrients, except fat, pass right through the walls of small blood vessels, or capillaries, until they get into the blood stream. Digested fat follows a different route. It too passes through the wall of the alimentary

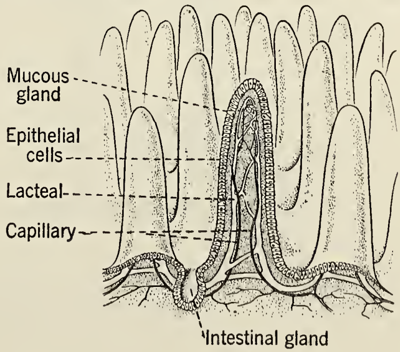


FIG. 12–6. The intestine is lined with millions of little fingerlike extensions. Each is covered with a skin, consisting of epithelial cells. Digested fat passes through this skin into a tube called a lacteal. Other digested food passes directly into the blood vessels. Note the intestinal glands.

canal, but instead of passing directly into the blood, it goes into a tube, the *lacteal,* then into the *thoracic* (thō·răs′ĭk) duct, from which it joins the blood stream in the neck. This passing of digested nutrients through the walls of the alimentary canal into the blood stream is called *absorption.* It is a type of *osmosis.* [See Fig. 12–6.]

Not all of the food we eat is digested and absorbed. A certain amount of material swallowed as food is not nutritious. This refuse, or waste, accumulates in the large intestine and should be expelled from the body daily.

*261. **Can we show that some liquids will pass through a membrane?** The following experiment can be performed to show that certain substances will pass through a membrane such as the intestinal wall.

Obtain a thistle tube, a square of gold beater's skin or of sheep intestine (cleaned and dried), molasses, a glass jar for holding water, a gummed label, two rubber bands, strips of cork, an iron laboratory stand with clamps, a small section of rubber tubing to fit the stem of the thistle tube, and a two- or three-foot section of glass tubing about the size of the stem of the thistle tube. [See Fig. 12–7.]

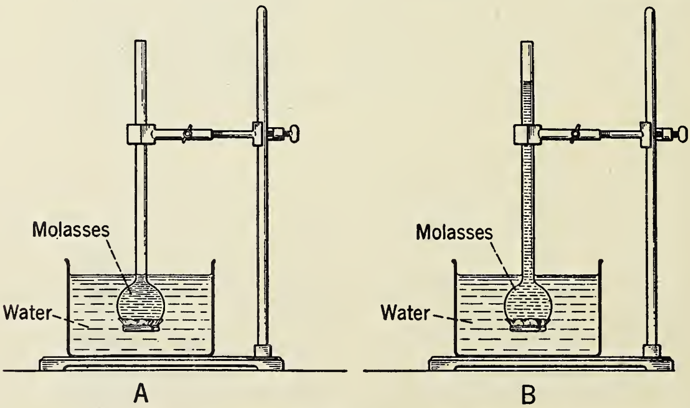


Fig. 12–7. The setup for the osmosis experiment is shown in A above. In a short time, water will have penetrated the membrane and raised the level of the molasses in the thistle tube, as shown in B above

Place the square of membrane in water to soften it. Plug the stem of the thistle tube, then fill the bowl of this tube level-full with molasses, letting the molasses go down into the stem a few inches. Take the membrane from the water and place it carefully over the bowl of the thistle tube. Stretch it carefully, and twist the rubber bands around under the lip of the bowl to hold the membrane in place. Make sure that there are no leaks. Now thoroughly wash the outside of the thistle tube. Use strips of cork in the jaws of the clamps of an iron stand and securely support the stem of the thistle tube so that the bowl is in the water in the jar. Remove the cork from the stem of the thistle tube. Make sure that the level of the molasses inside the thistle tube is at the same level as the water in the jar, by adding or removing water as necessary. Paste a strip of label on the outside of the jar to mark the level of the water. Finally cover the jar of water with a disc of cardboard, slit to the middle, to prevent evaporation of the water. Slip a piece of rubber tubing over the end of the stem of the thistle tube and attach the piece of glass tubing, safely supported.

Set up a control experiment, similar in every detail except that water is substituted for molasses in the thistle tube.

Very soon the level of the molasses in the stem of the thistle tube will move upward. Within an hour's time, it should be from 4 to 6 inches higher. By the following day it may have ascended several feet. If so, the level of the water in the jar will have lowered a little. In the second experiment, no change in level will have taken place.

*262. What is the interpretation of this experiment? Since no water was added to the thistle tube after the experiment was set up, it must be true that any water in the thistle tube has entered *through the membrane.* If the experiment has been operating for at least twenty-four hours, take some of the water in the jar and use the Fehling test to see if any molasses has come out into the water through the membrane. The test should leave no doubt that some

molasses has come out of the membrane into the water.

The law of diffusion states that fluids, if they are free to move, tend to spread out their particles from the place where there is the greatest concentration. Burn a feather in one corner of a room, and in a few minutes the unpleasant odor can be smelled in the opposite corner. The particles of burned feather scatter or diffuse out into the air. [See Fig. 12–8.]

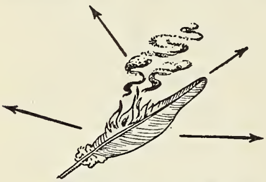


FIG. 12–8. If a feather is burned at one end of the room, in a few moments the strange odor will be noticeable in the opposite end of the room. Minute particles have spread or diffused throughout the air of the room.

In the present experiment, the water passes away from the jar (where there is nothing but water), through the membrane, into the molasses (where there is very little water). And the molasses passes from the place where the molasses was most concentrated, through the membrane, into the place where there was the least amount of molasses. This, then, is an example of diffusion through a membrane. Such diffusion is called *osmosis*. A thin liquid like water passes more rapidly through a membrane than does a thick liquid like molasses.

In the control experiment, no change in level occurs, because the concentration and pressure on both sides of the membrane are equal.

***263. How does osmosis apply to the absorption of digested food?** Digestion is the changing of food so that it will pass through the wall of the intestine by osmosis. All nutrients except water have to be digested. You can prove this by setting up two different experiments similar to the one where molasses was used. In one use raw egg white instead of molasses; in the other use starch and water. You will find that in neither case will these substances pass through the membrane. However, if to raw egg white you add a di-

gestive enzyme such as would be found in artificial gastric juice, and keep the contents warm for several days, the egg white will be digested. Now fill the thistle tube with this digested egg and set it up as before. Check the second experiment by adding some ptyalin to starch paste in a test tube, and keep the mixture at body temperature for several days. Then use this material instead of the original starch, in the thistle tube. In both of these cases the digested substances should readily pass through the membranes.

264. How does digested food reach the cells? The blood current in the large veins sweeps the newly absorbed food particles first to the liver. Here some of the sugar is taken out and stored in the liver cells. The rest of the food goes on to the heart. From the heart, the food particles go into the blood vessels which extend all over the body. When this food reaches the capillaries, the blood current is slowed down. The food has time, here, to pass out through the very thin walls of the capillaries. It is not difficult for some of this digested food to leave the capillaries. Close to the capillaries are cells of tissues such as muscle, bone, and nerve. Therefore, all the food that has escaped from any one capillary can easily be absorbed by whatever cells are nearest that particular capillary. In most cases the liquid called *lymph* passes this food from the capillary to the cells. The digested food is near the end of its journey, but it is still outside the cells. The mysterious force called osmosis again acts and brings the food into the living cells. Here the food is acted upon by the nucleus of each cell.

265. Why should we eat? Most persons like to eat, especially if they get plenty of well-prepared and appetizing food. In fact, some persons overdo the process of eating; one almost feels that they live to eat. From a biological standpoint, however, all of us *eat to live.* Why? Because food furnishes material for two great functions of the body: (*a*) *oxidation*, which releases the energy that we need for work and play, and (*b*) *assimilation*, which is the formation of protoplasm,

resulting in growth and repair of the body structure. Some foods are much more valuable than others for these two purposes. It is intelligent to give attention to the selection of nutritious foods. Foods containing starch, sugar, or fats are the most important kinds for furnishing energy for the body. Foods containing protein are necessary for the making of protoplasm. But protein can also be oxidized in the body.

266. How does assimilation of food differ from oxidation? When food is oxidized, energy is released for bodily activities. When this food is consumed in the body, more food has to be eaten. If a person is unable to get food, then for a time the protoplasm of his body cells becomes fuel. A person could live for a long time without eating any food, if he had water. But he would continually get thinner because some of his body material would be consumed. Cells need to be repaired and new cells are continually being formed in the body. This process of making protoplasm is called assimilation. The energy for this assimilation comes from oxidation of food, which itself is controlled by the same life principle which governs the changing of food into protoplasm. Assimilation is thus a constructive or building-up process, while oxidation is a destructive or tearing-down process.

267. Can food be burned in the body? You know that a mixture of gasoline and air can be exploded, or burned, in the cylinders of an engine such as that of an automobile. The energy thus released forces the pistons up and down in the cylinders. Food in the body acts like gasoline. When air is breathed into the lungs, the oxygen is absorbed by the blood and is thus carried to the cells. Digested food, as you have just seen, is also carried to the cells by the blood stream. Here the food meets the oxygen, and some of the food is actually burned. The burning is not rapid enough to resemble the explosion of gasoline. Yet the process in both cases is oxidation, the combining of oxygen with another substance. And the result in both cases is the ability to do work

by the release of energy, whether in the automobile engine or in the cells of the human body. The amount of energy released by food is measured in terms of the heat produced, or in calories. A large calorie, as you know, is the amount of heat required to raise the temperature of about one quart of water 1° C. or 1.8° F. An active, growing boy or girl or an adult requires enough food to produce approximately 3,000 calories each day.

268. How is the human body like a furnace? In the digestion and use of energy-releasing food, the human body acts like a furnace. If the lumps of coal are too big to burn well, we break them up before we throw them into the furnace. If the pieces of wood are too large, we split them up into smaller pieces. In a similar manner we use our teeth to cut our food into pieces and to grind them into small particles before we permit them to enter the stomach. We stoke the furnace in the house two or three times a day. We stoke our bodily furnace as we supply it with food.

We open the drafts of the furnace to permit oxygen to enter and oxidize the fuel that has been put on the grate. We breathe from 16 to 18 times per minute to permit oxygen to enter our lungs, pass into the blood, and oxidize our fuel foods in the cells of the body. The furnace in our house needs more fuel in cold weather. Our bodies use more foods in cold weather. Possibly the furnace is equipped with a thermostat to keep the rooms of the house at a more or less constant temperature. The skin is a sensitive thermostat which, with the aid of the nervous system, in healthy bodies keeps the temperature at about 98.6° F., summer or winter.

As the fuel in the furnace burns, or is oxidized, two waste gases, carbon dioxide and water vapor, are produced. They escape through the smoke pipe and the chimney. As the food in the body oxidizes, waste substances are formed. Two of these are carbon dioxide and water vapor. Both escape through the lungs. We can easily prove that the lungs are giving off water vapor if we breathe against a cold pane of

glass. The vapor condenses to form drops of water. Some of this water came from oxidation. We can prove that carbon dioxide is given off from the lungs by blowing our breath through limewater. The limewater turns milky, showing that carbon dioxide is present. Other wastes or oxides, chiefly *urea* (ū·rē′ȧ), are produced by oxidation of protein in the cells of the body. Such wastes dissolved in water are excreted by the kidneys.

In the furnace, some solid ash and refuse are collecting constantly. One must shake the grate regularly to get rid of such solid waste. The fire does not burn well if the grate becomes clogged with refuse. In the human body some solid wastes also are left in the alimentary canal after the work of digestion has taken place. The motion of the muscles of the stomach and of the intestine not only keeps our foods stirred up thoroughly to aid digestion, but also keeps the solid wastes moving along the intestinal tract. If our bodies are to be kept healthy, these solid wastes must be eliminated daily by the bowels.

In the furnace, if we shut off the supply of oxygen by closing tightly the drafts of the furnace, the fire goes out. In our bodies, if the supply of oxygen is shut off from our lungs as in drowning, the bodily fires go out and we die from lack of oxygen.

If our supply of fuel gives out, we cannot have a furnace fire. If our supply of food fails, we die from starvation.

269. What health rules apply to digestion? People from other countries who visit our country say that most Americans usually hurry. It is somewhat humiliating to have to admit that this impression is based upon facts. An immediate improvement in health would be gained if we would at least take time enough when eating. Attention to the following ten rules will pay good health dividends.

a) *Eat scientifically.* Make sure that the body receives foods in the proper proportions for assimilation and for oxidation. In general, the ratio should be protein one part,

fat one part, carbohydrates four parts. Each day growing boys and girls should have at least two ounces of protein. It is also important that calcium be included. This will be assured by including plenty of milk in the diet (a quart per child). No special attention need be paid to vitamins since they will be included normally in a scientific diet. Fresh vegetables should include both leafy and raw forms, such as lettuce, cabbage, and carrots. [See Fig. 12–9.]

b) *Chew food thoroughly.* Time so spent is not lost. Teeth and gums are strengthened and exercised; more saliva is mixed with the food; the food itself is broken down into smaller particles; and more flavor is secured from the food.

c) *Do not overeat.* The stomach may thus be overloaded, and the body be burdened by excess fuel or building material. Too much food in the intestines may bring about indigestion, also fermentation in the large intestine. Poisons which are produced by such conditions may seriously impair health. Eat to live, but don't live to eat.

FIG. 12–9. Kale is a valuable green vegetable. It is eaten cooked or raw. (*Courtesy "Journal of Living"*)

d) *Do not eat between meals* unless upon the advice of a physician. It usually takes the edge from a normal appetite.

e) *Drink plenty of water.* Take a glassful upon rising, and at least two glassfuls between meals.

f) *Eliminate daily.* Fruits are of value in forming good habits of elimination, as is exercising in the open air and the drinking of plenty of water.

g) *Do not eat much or too quickly if you are extremely tired or worried.* Indigestion is likely to follow.

h) *Keep the teeth clean.* The total area of possible tooth infection is said to be over twelve square inches. Tooth decay may interfere seriously with health.

i) *Pay no attention to special diets* except upon the advice of a physician. Also ignore statements such as the one that carbohydrates and protein must not be eaten together.

j) *Do not bathe or swim within an hour after eating.* So much blood might thus be drawn away from the stomach and intestines that they would not function properly.

270. How can the same kind of food become different structures? A rabbit eats grass and grains. So does a grasshopper. The green vegetable food digested in each of these animals is changed into the bodily structure of that animal. The rabbit eats food and it is used for the growth of floppy ears and beautiful soft eyes and the other parts of a normal rabbit. When the grasshopper chews vegetation and digests

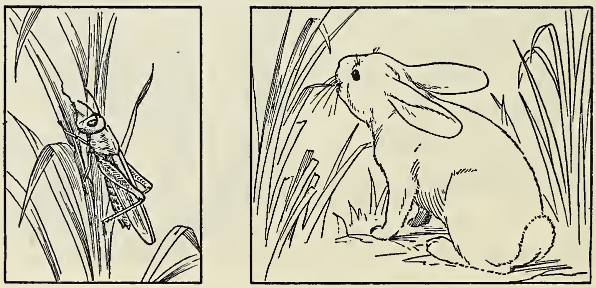
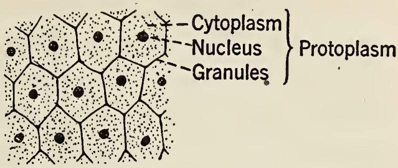


FIG. 12–10. The grasshopper and the rabbit both eat grasses. In one case grass becomes grasshopper; in the other, rabbit.

FIG. 12–11. Under the microscope examine some scrapings from the inside of your cheek and you will see epithelial cells. As arranged in the skin, they form a pattern like the diagram.



it, he provides material for two pairs of wings, strong flying muscles, spiny legs, and so on. [See Fig. 12–10.] Formless, pasty food is changed into structures and parts of animals by assimilation. Perhaps the most wonderful thing about assimilation is that the same food can be changed into such different structures as the rabbit and the grasshopper. The food itself, therefore, has nothing to do with the process. It is acted upon by life; the food does not itself *do* anything.

271. Are all organisms made up of cells? You have already learned that not only rabbits and grasshoppers, but all other animals — all plants, too — are made of cells. Certain plants and animals are composed of but one cell.

Since assimilation takes place in cells, we should learn more about cells to understand assimilation better. Your arm is covered with skin. Underneath the skin there is firm muscle. If we examine some of this muscle under the microscope, we see banded divisions, each with a nucleus. As you know, most animal cells do not have definite cell walls like those of plant cells. Although a skin, or *epithelial* (ĕp′ĭ·thē′lĭ·*ă*l) cell, does have a boundary or outer membrane, it is one example of an animal cell. [See Fig. 12–11.] You have learned that the living stuff of a cell is *protoplasm* and that each cell normally possesses a *nucleus*. The protoplasm that is between the nucleus and the membrane is called the *cytoplasm* (sī′tō̍·plăz′m). Mixed in with the cytoplasm may be lifeless substances, such as oil and granules.

***272. Of what chemical elements is protoplasm composed?** Robert Hooke, who first discovered cells in plants one hundred years ago, never learned of what chemical sub-

stances protoplasm is composed; chemistry had not advanced enough at that time to disclose the secret. Nor did Von Schultz, the man who discovered and named protoplasm. Today such facts are common knowledge. Scientists list eighteen kinds of elements found to some extent in protoplasm. [See Fig. 12–12.] In order of quantity present they are:

a) Oxygen	*b*) Carbon	*c*) Hydrogen
d) Nitrogen	*e*) Calcium	*f*) Phosphorus
g) Potassium	*h*) Sulfur	*i*) Sodium
j) Chlorine	*k*) Magnesium	*l*) Iron
m) Manganese	*n*) Iodine	*o*) Silicon
p) Fluorine	*q*) Zinc	*r*) Copper

Although it is well known that protoplasm consists of these elements, no scientist has ever been able to produce protoplasm, the living substance, by any combination of these elements. Nor can living organisms eat these elements as such and make protoplasm. Several of the elements, such as chlorine, iodine, phosphorus, fluorine (flōō′ō·rēn), and others, in pure form, would be violent poisons to most living things, and certainly to human beings. They have to be combined in such forms that living things can use them. Such combinations are called *compounds*. The most important compound for making protoplasm is protein. In fact, without protein and water, no protoplasm can be formed. Protein is composed of carbon, hydrogen, oxygen, nitrogen, phosphorus, sulfur, and other elements. The remaining elements found in protoplasm are usually found as mineral substances coming from various foods such as milk, vegetables, and fruits.

Normal assimilation will not take place even when the needed nutrients are present unless substances called vitamins are also present in the food, and other substances called hormones are secreted by the ductless glands in the body.

273. Do we know how food is changed into protoplasm? You often hear certain foods described as body builders.

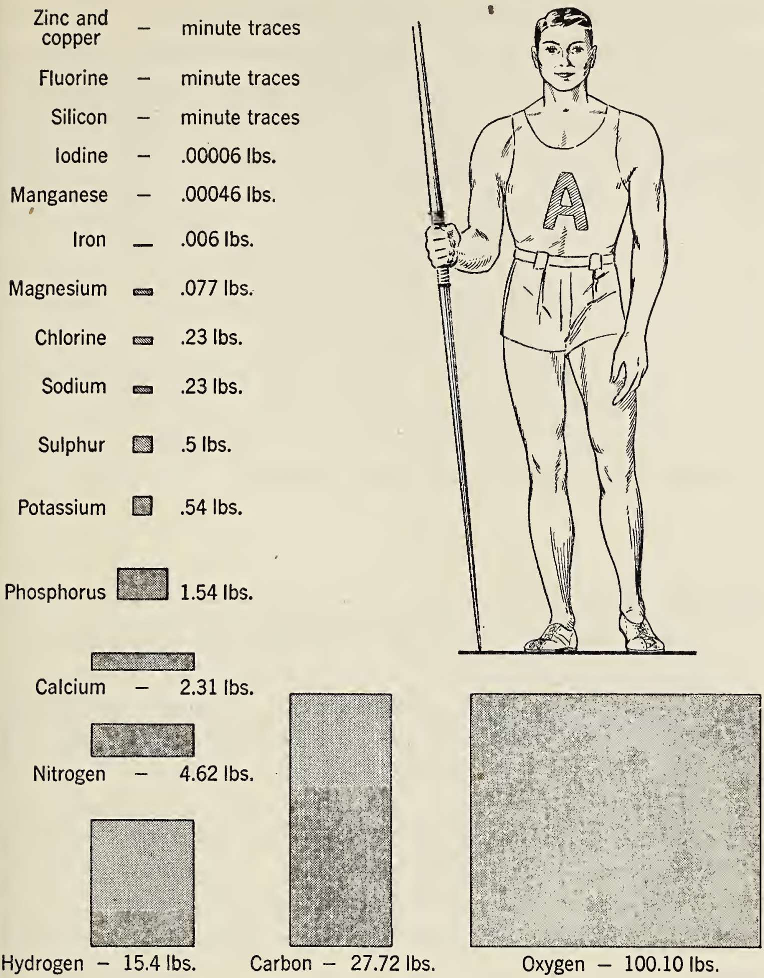


Fig. 12–12. The 18 elements composing the body of an athlete weighing 153.27 pounds are shown graphically in proportions.

Unless food is intelligent, which no one believes, how can it build up the body? It is better to speak of foods that can be assimilated as *building material* for the body. It is very easy to write or read that food can be changed into protoplasm by assimilation. Yet, the exact process of changing nonliving substances such as the chemical elements into pro-

toplasm, is perhaps the world's greatest mystery. No scientist knows how it is done. The eighteen chemical elements are still there. In protoplasm that strange force, *life,* is expressed through these elements. The protoplasm of a living organism grows; it repairs worn tissues; it reacts to stimuli, and it reproduces. Lifeless elements can do none of these things. The body of a dead animal, for instance, apparently has the same chemical composition as it had when alive. Life alone seems to be the missing factor. What is life? What is its origin? How can it be produced? How did it begin on this earth? Perhaps some boy or girl studying this book will be fired with an enthusiasm to be a *biochemist* and help answer these profound questions. So far, no scientist has been able to answer them.

QUESTIONS

1. Define *digestion.* Can food be digested by chewing it?
2. What is an enzyme?
3. Can you name all the parts of the human alimentary canal?
4. What part of the alimentary canal is the most important for the digestion of food?
5. What fluid digests fats?
6. Can you name two digestive fluids that will digest protein?
7. What functions has saliva?
8. How many teeth are in the normal permanent set?
9. How can you experimentally prove that saliva can digest starch?
10. What kind of digestion takes place in the stomach?
11. How does digested fat reach the blood?
12. How do the other digested nutrients get into the blood?
13. What is absorption? Why is it a kind of osmosis?
14. Why must we eat to live?
15. Can you make a full comparison of the human body with a furnace?
16. How many chemical elements have been found in the human body?

17. Can you name the six most important elements found in protein?

18. What are some of the other twelve elements?

19. Can you name six foods, each containing a considerable amount of protein?

20. What part of the cell is chiefly concerned with the formation of protoplasm?

21. Why is protoplasm always associated with life?

22. Are all parts of the cell alive?

23. Why cannot scientists take the eighteen elements of which the human body is composed and by combining them in the right proportions make protoplasm?

24. What can the living cells of an animal do that the cells of that animal, when dead, cannot do?

25. What rules of health apply to the care of the digestive system?

Some things for you to do

1. Under the direction of your teacher, try one or two other experiments in digestion, such as using white of egg and artificial gastric juice; mixing meat and pancreatin; and making an emulsion by shaking up a little olive oil with water and a little, weak potassium hydroxide in a test tube.

2. Use a mirror to locate the openings of the different salivary glands in the mouth. Wipe the indicated regions dry with a clean handkerchief and then note the fresh flow of saliva.

3. Find out all you can about Robert Hooke and how he came to discover cells.

Think about these!

1. Can you explain why a person becomes unconscious if breathing is suspended for only three minutes?

2. If a fish can take oxygen in from the water through its gills, why cannot a human being absorb the oxygen from water when it gets into his lungs?

3. How is the diaphragm of value in human breathing?

4. Does the chest get larger as the result of taking air into the lungs?

Words for this chapter

Mucous membrane. The skin lining the mouth, nostrils, throat, and other parts of the digestive and respiratory systems.

Pharynx (făr′ĭngks). The throat.

Trachea (trā′kė·*ȧ*). The windpipe.

Bronchus (brŏng′k*ŭ*s). One of the two main branches of the trachea.

Alveolus (ăl·vē′ȯ·l*ŭ*s). An air sac.

Mucus. The secretion of the mucous membrane.

Timbre (tĭm′bẽr). Quality of the voice.

Allergic (*ă*·lûr′jĭk). Sensitive to foreign substances.

Inoculation. Planned injection of something, such as antitoxin, under the skin, usually with the purpose of counteracting disease.

Immunity. Freedom from; power of resisting a disease.

CHAPTER 13 ______________ UNIT 6

Why Do We Breathe?

274. What organisms breathe? Every living thing, either plant or animal, from the smallest one-celled organism up to the mighty whale and the huge redwood tree, requires oxygen. Plants, and many of the lower animal forms, absorb oxygen without making any breathing movements. In higher animals, however, such as the fish, frog, reptile, bird, mammal, and insect, there are definite movements of certain parts of the body, in bringing air into the body and getting it outside again. [See Fig. 13–1.]

***275. How do different animals breathe?** The insect breathes by forcing air in and out of holes in the sides of its body. The fish opens and closes its mouth, causing a current of water containing oxygen, dissolved from the air, to pass over the thin gills. The frog forces air into its mouth and lungs by movements of its throat. The snake causes air to come into its single developed lung by expanding its ribs. The bird also brings air into its lungs and its air sacs by movements of its ribs. The mammal uses either its ribs or

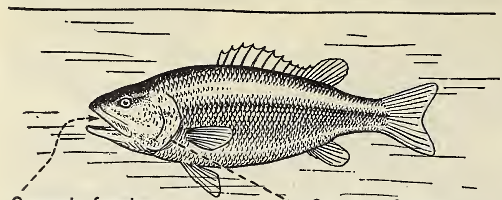


FIG. 13–1. Water, containing dissolved oxygen, enters the fish's mouth and passes out over the gills. The thinnest parts of the gills absorb much oxygen and pass off carbon dioxide.

a structure entirely different from that possessed by any of the preceding groups – the diaphragm.

276. What is human breathing? Breathing movements take place in our own bodies throughout life, whether we are awake or asleep. In fact, in the case of serious accidents, the doctor is encouraged if he finds that the patient is breathing, for that is always a sign of life. When a baby is born, its first cries are a welcome sign that its lungs are working. If a person's breathing were to be suspended for only three minutes, he would lapse into unconsciousness, because the brain requires oxygen continuously. Without a regular supply of oxygen from some source, life ceases in any organism except certain bacteria which live without free oxygen.

The taking of air into the lungs is called *inhaling*, or *inhalation*. The forcing of air out of the body is called *exhaling*, or *exhalation*.

277. Why do we breathe? Light a candle and then cover it with a glass jar. In a few seconds the flame will become pale and then disappear. The candle flame has gone out because the supply of oxygen inside the jar has been used up. Just as surely as the candle flame – in fact, all fire – requires free oxygen to continue burning, so does every plant and animal except certain bacteria. Every cell of each of these organisms gets energy by burning food or protoplasm in a process called *oxidation*, as you have already learned. Therefore a supply of oxygen must be present continuously.

278. What are the parts of the breathing system? Every normal human being is born with two lungs; a windpipe and

air passages to permit the air to flow in and out of the lungs; chest walls to cover and protect the lungs; and muscles, ribs, and a diaphragm to assist in breathing. The two lungs, the windpipe and the air passages, and the ribs and diaphragm, all taken together, constitute the *respiratory system.*

In the nostrils are many hairs, which strain out the dust particles from the incoming air. It is important, therefore, to breathe through the nostrils instead of through the open mouth. The nostrils are lined also with a moist, warm, *mucous membrane,* which catches dust and bacteria, and whose temperature of 98.6° F. takes the chill from the incoming air. [See Fig. 13–2.]

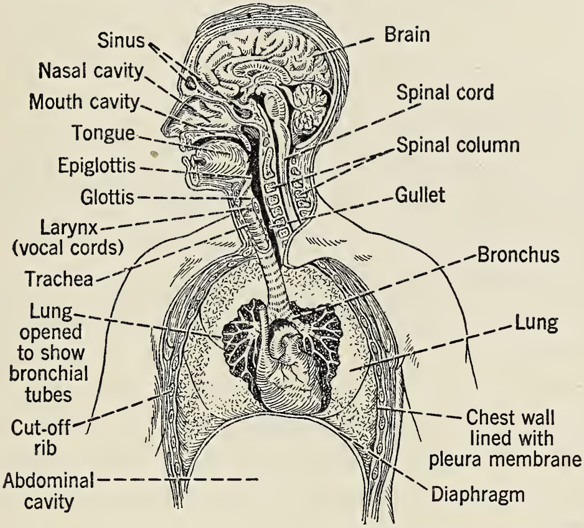


FIG. 13–2. Notice the organs of the head, neck, and chest.

279. How does air get into the lungs? Air entering through the nostrils or through the mouth, immediately passes into the *pharynx,* or throat. Below the throat is the entrance to the windpipe. This opening is called the *glottis.* It is provided with a little trapdoor, or flap, which closes when the food is being swallowed. The windpipe, or *trachea,* has rings of cartilage in its walls. This stiffens them

and prevents their collapse. The upper part of the trachea is enlarged to contain the vocal cords, and is called the *voice box,* or *larynx.* The trachea extends down about six inches, then divides into two branches, each of which is known as a *bronchus.* Each bronchus enters a lung and divides into many *bronchial* tubes or *bronchioles* (brŏng′kĭ·ōlz). Each bronchial tube branches many times. Each tiny branch finally terminates in a thin-walled air sac. An air sac is also called an *alveolus.* From this information, see if you can trace the path of incoming air from the nostrils to an air sac. Then reverse the problem and state the path taken by air being exhaled from the air sac to the outside atmosphere.

280. How do the cilia of the mucous membrane operate? All the tubes and cavities through which air passes in inhalation or exhalation are lined with the same thin skin — mucous membrane — that is found in the nostrils. The *mucus* secreted by this membrane tends to moisten and warm the air, and to catch foreign particles.

In the trachea and most of its branches, the cells of the mucous membrane are provided with microscopic hairlike structures called *cilia* (sĭl′ĭ-*ȧ*). When these cells are greatly magnified, their outer surface looks like a forest of tiny whips. If you could look into a bronchus while it was living and doing its work, you would see each of the cilia making a lashing movement. The patches of cilia would be waving in the direction of the air leaving that part of the lungs. In this

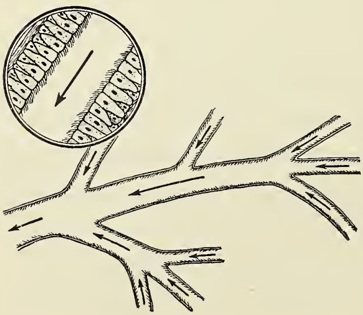


FIG. 13–3. The air tubes of the lungs are lined with cilia. These microscopic hairs keep waving in the direction the air takes in leaving the lungs, thus carrying foreign particles out of the lungs.

way, mucus and tiny foreign particles are passed along from one group of cilia to another until they reach the trachea. From the trachea they are passed up to the throat. By reference to Figure 13–3 you can see that in order to move particles outward, the cilia in the upper lobe of the lung would have to lash downward, while those in the lower part of the lung would be lashing upward.

281. How can one see cilia working? Mount a tiny piece of the gills of a freshly opened hard-shell clam on a microscope slide in a drop or two of the liquid found inside the clam shell. Place this under the low power of the microscope and move about until a patch of active cilia are found. [See Fig. 13–4.] Human cilia lash back and forth in precisely the same way.

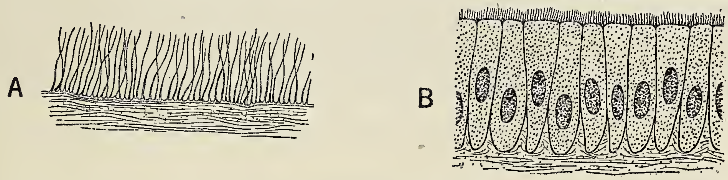


Fig. 13–4. Living cilia on the edge of a portion of the gill of a clam are shown in A above. In B are shown mucous-membrane cells found in the human throat.

282. How do the cilia work together? There are enormous numbers of these cilia. It is estimated that there are many million mucous-membrane cells in one person's lungs and air passages. Each mucous-membrane cell supports about twenty-five cilia. In your own lungs and air passages, therefore, there may be 85,000,000 – more than the number of human beings in the United States east of the Mississippi River.

An army of 85,000,000 individuals has never yet been assembled. If such a vast throng of men could be assembled, they would require a tremendous amount of training and leadership before they would work together. The cilia, how-

ever, too small to be seen without a microscope, scattered through the lungs, with no means of seeing, with no direction, work together for our health, day and night, throughout life. If such co-ordinated movements as these cilia perform were accomplished by millions of intelligent human beings, the world would applaud it as a brilliant achievement. Have you any explanation of how these millions of structures can work together for your good? The fact that you probably did not know that you possessed such an army of beneficial structures in your chest, working for you even while you are reading these lines, is proof of the intricate structure and the amazing functions of the body. But it does not explain the unified activity of the various parts of the body.

What would happen to the lungs, and eventually to your life, if these millions of cilia were to *lash inward* instead of outward? All dust and other foreign particles would then be passed further into the lungs, which would soon become clogged like a vacuum cleaner which could not be emptied. Fortunately, so far as we know, the cilia do not change their habits.

*283. **How do we inhale?** Breathing is a mechanical process, depending entirely upon air pressure. A vast blanket of air, several hundred miles thick, covers the earth. [See Fig. 13–5.] This air is a mixture of invisible gases, yet it has weight, as you learned when you began the study of air last year. At the level of the sea, air presses with a force equivalent to 14.7 pounds per square inch on the surface of every object, including the human body.

If the diaphragm is lowered or the ribs raised, the chest cavity is made larger. This causes *decreased* pressure inside the lungs. We know that air is pressing against all surfaces with a force of 14.7 pounds per square inch. If the pressure inside the lungs becomes less than that, and the person's nostrils or mouth are open, we know that air is going to flow into the lungs. It comes in by the only entrance there is, by the mouth or nostrils, throat, and windpipe. If

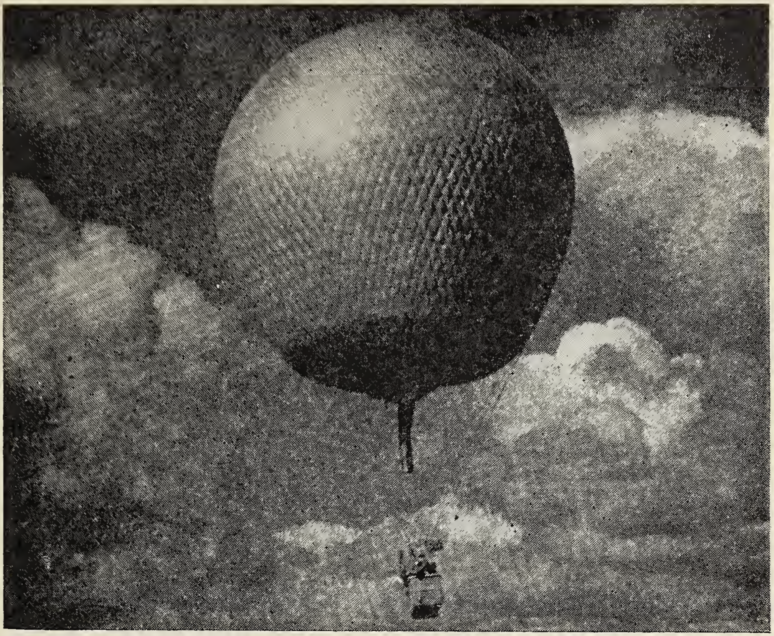


FIG. 13–5. An observation balloon, high in the blanket of air which covers the earth. (*Official U. S. Navy photograph*)

there were a hole in the side of the person, and the chest cavity was opened to the atmosphere, air would also enter the chest cavity through the unnatural hole. But this air would only go into the chest cavity, not into the lungs, and would be of no benefit to the person. In inhalation, air is being forced into the lungs by the pressure from the atmosphere, in the attempt to fill the space in the chest cavity, and the lungs expand. [See Fig. 13–6.]

*284. **How do we exhale?** Exhalation follows inhalation. The diaphragm and the chest walls are elastic. If they have been stretched to permit inhalation of air, when relaxed they tend to take their normal size. How does this affect the size of the chest cavity? We see that with this new change in the size of the chest cavity, the air particles inside the lungs are going to be crowded and the pressure there *increased.* As soon as this pressure becomes greater

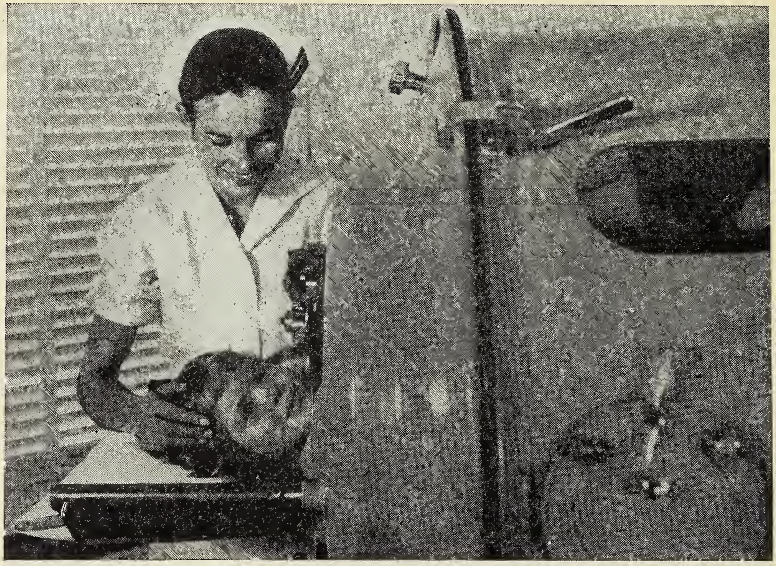


FIG. 13–6. A person whose diaphragm has been paralyzed, as by infantile paralysis, can be kept alive by a marvelous instrument called an iron lung. This machine produces rhythmic pressures on the body, causing artificial inspiration and expiration. (*WPA photo*)

than the surrounding air pressure, the air begins to go out of the lungs.

***285. How can breathing be shown by an artificial lung?** By means of the apparatus shown in Figure 13–7, you may be able to understand more clearly what has been discussed in the preceding paragraphs. Here the glass jar that represents the chest cavity is transparent, so that you can see what is taking place inside. When the rubber (representing the diaphragm) is pulled down, how will the size of the interior of the jar (representing the chest cavity) be changed? Is there an entrance to the interior? Where? When the artificial diaphragm is lowered, air will enter through the artificial trachea and swell the artificial lungs. Which takes place first, enlarging the rubber lungs or increasing the artificial chest cavity? Moving the rubber diaphragm up-

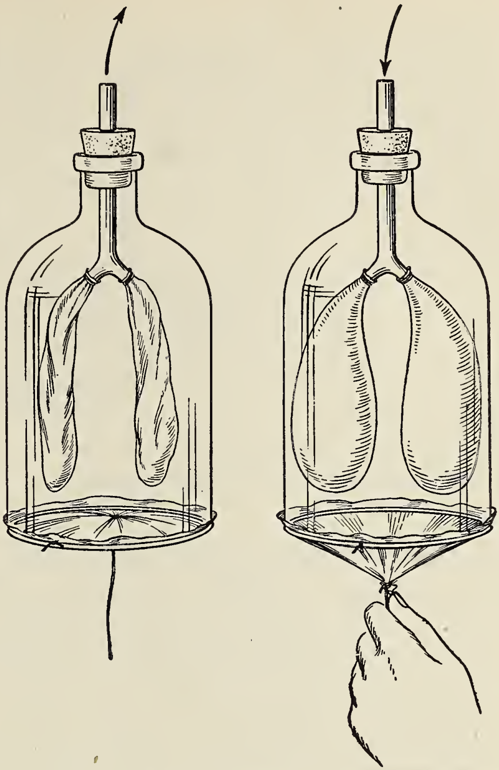


Fig. 13–7. An artificial chest cavity with artificial lungs can be easily constructed. At the left we see the rubber lungs hanging from the glass trachea. At the right we see that the diaphragm has been pulled down and air is being pushed by atmospheric pressure down into the glass trachea and into the rubber lungs, distending them. Can you explain why? In the human being, what pulls the diaphragm down? Why does this affect the size of the lungs?

ward will have a different effect. Will the artificial chest cavity be made larger or smaller? Can you see why the air will be forced out by this action and why the rubber lungs will collapse? There are many ways in which this apparatus resembles the windpipe and the lungs in structure and action.

*286. **What is the capacity of the lungs?** The amount of air that the average adult can breathe in is somewhat over a gallon. This can be measured by an instrument called the *spirometer* (spī·rŏm′ė·tẽr). The following simple device also can be used to measure the breathing capacity, sometimes called the *vital capacity*, of an individual. Secure a gallon glass bottle such as is used for distributing spring water. [See Fig. 13–8.] With a file, a wax pencil, or a label, mark on

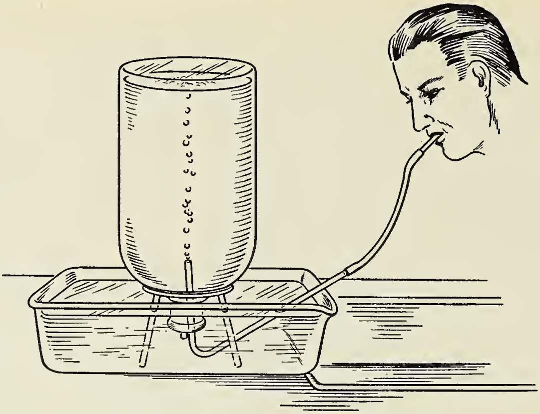


FIG. 13–8. The capacity of the lungs can be measured by a simple homemade spirometer, as shown here.

the outside the level of a quart of water which has been poured into the bottle. Similarly mark the level of two quarts, three quarts, and four quarts. Fill the bottle with water, then invert the neck in a collecting tray filled with water. It may be necessary to use extra support for the bottle. Introduce a rubber tube of fair size into the bottle, being careful not to pinch the tube at the neck of the bottle. Air blown into the bottle will rise to the top of the water and displace an equal amount of water. A pupil to be tested inhales as much air as he can, and then blows through the rubber tube. When he has expelled all the air from his lungs that he can, the amount of air in the bottle can be measured.

Ordinarily when a person inhales, he takes in only about a pint of air (from 20 to 30 cubic inches). This is called the *tidal air*. As the preceding experiment shows, each of us, even growing boys and girls, has a breathing capacity far beyond that. We would all unquestionably benefit if we took in more air than we usually do at each breath. We could rather easily establish the habit of deep breathing, with value to our health.

There is approximately a quart and a half of air constantly in the lungs. This is called the *residual* air. It is not breathed out, and it is never lost unless it is partly displaced by a shock or unless it is replaced by water in the lungs, as in drowning. Many boys have had the experience of having their "wind knocked out," as it is called, by a sudden blow over the stomach. This affects a group of nerves called the *solar plexus,* producing a sort of cramp in the breathing muscles and stopping inhalation for a time.

287. What is the average rate of breathing? An adult inhales and exhales about fourteen or fifteen times a minute. Young persons and nervous persons breathe more rapidly than that. As is well known, the rate of breathing increases with muscular activity or with mental excitement. Can you tell why?

***288. How are persons affected by low pressure?** Human beings are adapted to live in an atmospheric pressure equivalent to 14.7 pounds per square inch (at sea level). As one climbs high mountains or ascends high in the air by balloon or airplane, the barometer shows that the air pressure is greatly lessened. [See Fig. 13–9.] At 28,000 feet, the highest mountain height man has attained, the air pressure is only one-third of that at the sea level. Under these conditions it is

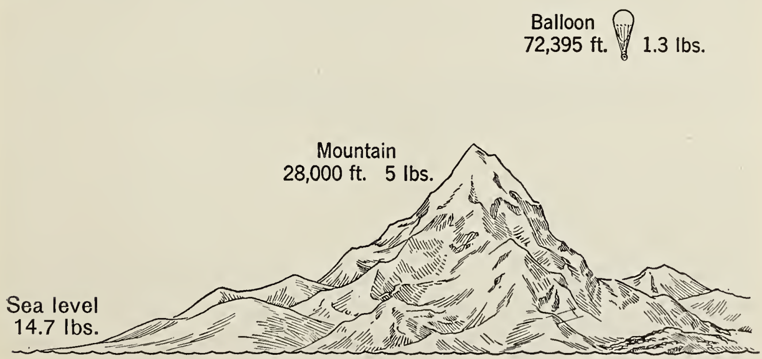


Fig. 13–9. Air pressure, 14.7 pounds per square inch at sea level, gets steadily less the higher one goes.

difficult for a person to get sufficient oxygen into his blood. Difficulty in breathing is experienced; symptoms of lack of oxygen in the body, such as blueness of face and hands, appear; and the person may even become unconscious. A person with a weak heart should avoid such regions of low atmospheric pressure.

Aviators who ascend into the stratosphere, to an altitude of over 30,000 feet, are provided with electrically warmed suits to maintain body temperature, and with oxygen tanks or special means for renewing the air within the compartment. Modern scientific devices are installed on passenger planes flying at great heights, to provide sufficient oxygen and to keep the temperature within the planes as unchanging as the temperature in a modern air-conditioned room. [See Fig. 13–10.]

***289. How are persons affected by high pressure?** On the whole surface of the earth, there are only a few places below sea level where one would find natural atmospheric pressure higher than 15 pounds per square inch. However, there are many artificial conditions in which men have to endure

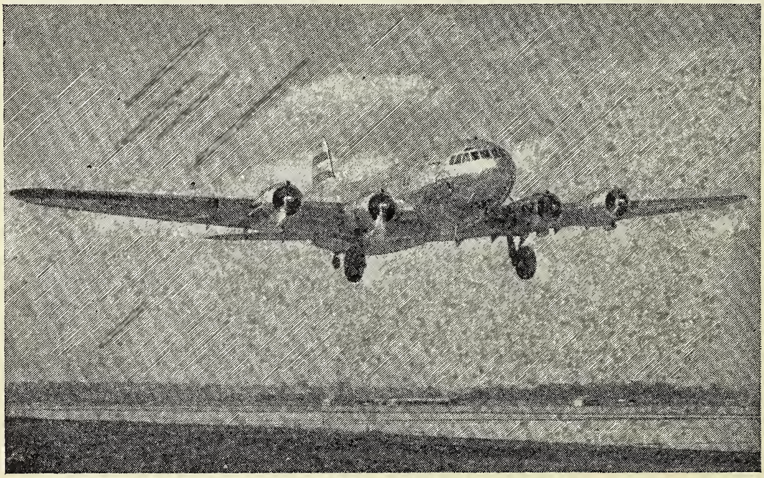


Fig. 13–10. A sealed airplane is leaving the airport to climb into the stratosphere. (*Courtesy TWA*)

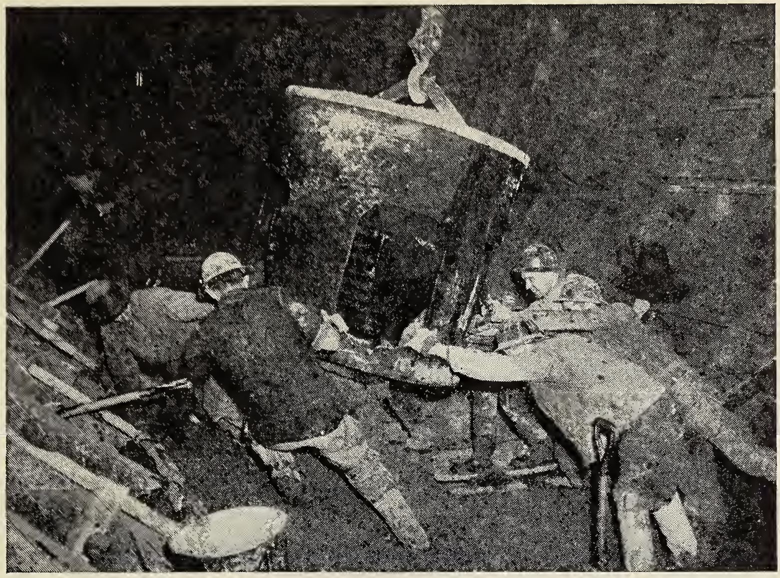


FIG. 13–11. In tunnel construction, "sand hogs" may work 100 feet below sea level, under air pressures much higher than normal. (*Courtesy New York City Tunnel Authority*)

much higher pressures. Whenever a chamber called a *caisson* (kā′sŭn) is used to lay the foundations of a bridge or to construct a tunnel under water, air under high pressure must be used to keep the water out of the caisson. [See Fig. 13–11.] Men who work in caissons under such increased pressure are called "sand hogs." There is not much danger in entering the caisson, though frequently there is discomfort until one is used to the pressure. The danger comes when the men leave. It is very important that they go into an airtight room where the air pressure is gradually lowered to normal. If a "sand hog" were to come quickly into normal atmospheric pressure, bubbles of gas would form in his blood stream, causing terrific pain. This condition is called "the bends." If such bubbles form in the brain, they may cause death.

290. What happens in the lungs? It is important now to consider why we breathe, and what takes place in the lungs.

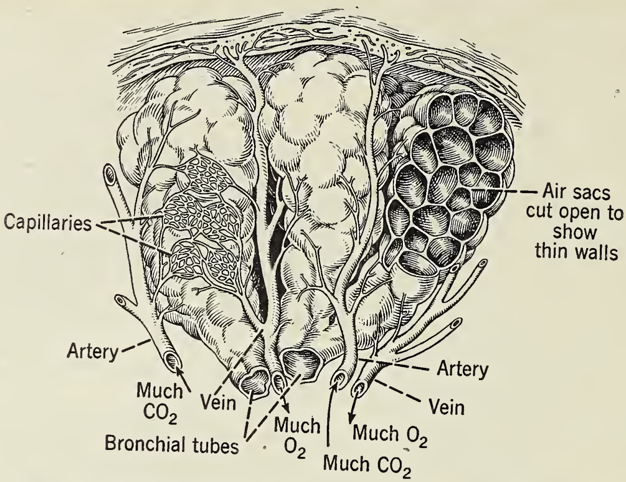


FIG. 13–12. The air sacs of the lungs are covered with a network of blood vessels. Arteries bring carbon dioxide (CO_2) to the air sacs. Veins carry away oxygen (O_2) from the air sacs.

The lungs themselves are inert; they do not assist in taking air in and they do very little in forcing air out.

Lung tissue appears almost frothy, because of the enormous number of air sacs, of which there are about 700,000,000 in one individual. The lung itself is pink because of the millions of capillaries which extend throughout the lungs and which contain blood. [See Fig. 13–12.]

You can best understand the function of the lungs by considering one air sac, or alveolus, and seeing what happens there. By reference to Figure 13–13, you will see that each

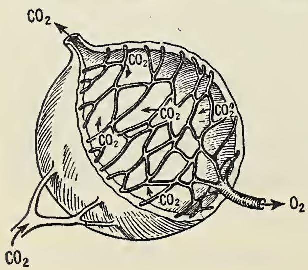


FIG. 13–13. Capillaries surrounding each air sac are constantly giving off carbon dioxide, which passes out of the air sac to be exhaled. The oxygen in the air sac combines with hemoglobin in red blood cells and is carried away in the blood.

alveolus is in close contact with a capillary. The capillary is the smallest of the blood vessels of the body, and its wall is extremely thin. The wall of the alveolus is equally thin. So the air in the alveolus is separated from the blood in the capillary by two of the thinnest membranes in the body.

Now suppose that freshly inhaled air has filled one of the air sacs. One-fifth of this air is oxygen. But there is little or no oxygen in the blood flowing through the capillary next to the air sac. Where there are many particles of oxygen on one side of a thin, moist membrane and very few particles or none on the other side, by the law of osmosis there would be a movement of these oxygen particles through the membrane toward the region where there are fewer particles. This explains how oxygen enters the blood — by osmosis.

291. What is the role of the red blood cell? Only a certain part of the blood, the red blood corpuscles, or cells, can carry oxygen. The oxygen that has just come into the blood immediately penetrates the membrane covering the red blood cells, and goes into the interior of the cells. This again is an example of osmosis. Here it combines with an iron compound called *hemoglobin* (hē′mō·glō′bĭn), which is contained in the red blood cells. This makes a temporary union of oxygen and iron called *oxyhemoglobin*. After this oxygen has been added, the red blood cell is a much brighter red. The oxygen, now chemically united with iron, starts on a journey to the distant cells of the body that need this precious gas. On the average, only about one-fifth of the oxygen present in the air sac actually gets through the capillary wall and enters red blood cells. More oxygen would be taken into the blood if we breathed more deeply.

292. What wastes are excreted from the blood in the lungs? Something else has been taking place in the air sac. As you know, some of the oxygen has gone into the blood. But more and more *carbon dioxide* has been coming out into the air sac. The blood passing through the capillaries of the wall of the air sac has come from various cells of the body,

some near at hand and some far distant. From all these cells it has been gathering carbon dioxide, which these cells have given off as a waste. This carbon dioxide is carried mostly by the liquid part of the blood, but some is brought back by the red blood cells. Some moisture also passes into the air sac from the blood. The carbon-dioxide gas and the moisture escape from the lungs at the next exhalation.

This process of oxygen passing *from the air sacs into the blood,* and carbon dioxide and water passing *from the blood into the air sacs,* takes place in the millions of air sacs of the lungs without the slightest assistance from the conscious mind. It is as sure and prompt when we are asleep as when awake. This exchange of oxygen and carbon dioxide in the lungs is called *external respiration.*

*293. **What is the composition of inhaled air and of exhaled air?** Dry atmospheric air which is breathed in, or *inspired,* ordinarily contains:

Nitrogen	78%
Oxygen	21%
Carbon dioxide	.03%
Argon	1% (or less)

Expired air, as it comes from the lungs, usually has the following composition:

Nitrogen	78%
Oxygen	16%
Carbon dioxide	4%
Argon	1% (or less)

294. **What is meant by internal respiration?** The lungs do not function just for themselves. Their work is for the entire body. Every cell outside the lungs is entirely dependent upon the lungs. The blood stream is the agent which brings the oxygen to the cells of the body and carries away carbon dioxide.

The capillaries are so small that they penetrate among cells and thus reach the remotest and deepest parts of the

FIG. 13–14. Internal respiration is the absorption and use of oxygen by the body cells and the passing off of carbon dioxide from these cells. Oxygen and carbon dioxide pass through lymph in the spaces around the cells.

body. Wherever the cells are deficient in oxygen, this gas diffuses through the capillary walls and then into the cells where there is little or no oxygen. This oxygen combines with various food substances in the cells by the process of oxidation. [See Fig. 13–14.] In this case there is no flame, but heat is produced just as by a slow fire. The great importance of oxidation to the cells is the release of energy for the activities of the living cell. Just as ashes are produced by an ordinary wood fire, so there are products of this oxidation in cells. These products are called *oxides*. The commonest element in food which combines with oxygen is carbon. Carbon, when oxidized with plenty of oxygen, produces carbon dioxide. Hydrogen also is oxidized in the body, forming *hydrogen oxide,* commonly called water. As soon as carbon dioxide accumulates in the cells, it passes out into spaces around the cells. These spaces are filled with a liquid called *lymph.* The lymph absorbs the carbon dioxide and carries it off through lymph tubes until the lymph finally enters the blood. When the blood reaches the lungs, the carbon dioxide diffuses through the walls of the capillaries into the interior of the air sacs. Then it is breathed out. Other wastes, such as ammonia, are formed by the breaking down of protein. In the liver, these protein wastes are changed into a substance called *urea,* and are discharged into the lymph and the blood. When the blood passes through the kidneys, this urea, dissolved in water and now called *urine,*

is taken out of the blood and excreted through the bladder.

Internal respiration, then, is a term referring to the use of oxygen by all the living cells of the body.

*295. **How does our voice box operate?** One of the uses of the breath is in the production of sound. The apparatus which produces sound is the voice box, or larynx, at the top

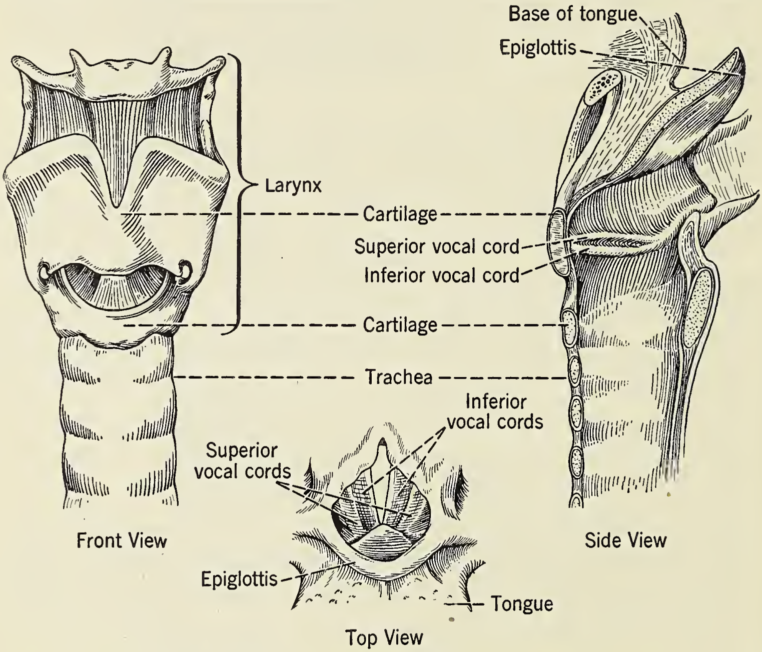


FIG. 13–15. The larynx, or voice box, is in the throat at the top of the trachea, or windpipe. It is a simple structure, but the vocal cords, located there, form the apparatus by means of which we speak, shout, or sing.

of the trachea. [See Fig. 13–15.] In this small structure are two membranous cords which somewhat resemble rubber bands. By means of muscles they can be shortened or lengthened; brought close together or separated. In Chapter 8 you learned that if two strings of the same kind of material and the same size, differing only in length, are stretched the same amount, the shorter string will give a

shriller- or higher-pitched sound when plucked. This is the secret of playing a stringed instrument like a violin. The finger is placed on the string, thus shortening the part of string that is free to vibrate. The higher on the string the finger is placed, the shorter the part of the string becomes, and the higher the pitch of the note that is produced. Similarly, the pitch of the human voice depends upon the length and tension of the vocal cords. The tension can be changed more or less as the individual desires. For a high pitch, such as a high note produced in singing, or a shriek, the vocal cords of a person would be stretched almost as much as possible. The higher pitch of the natural voice in boys and girls and in women proves that their vocal cords are shorter than are those of men. When a boy's voice "changes," about the time when he is from twelve to fourteen years old, it is a sign that his vocal cords are getting longer, and that his voice thereafter will be deeper. The vocal cords of women are

FIG. 13–16. Since a woman's vocal cords are shorter than a man's, her voice is higher pitched. From low to high, singing voices are classified as bass, baritone, and tenor (men), alto, mezzo soprano, and soprano (women). Lily Pons has one of the highest pitched voices of today's well-known singers. Few voices can range more than two octaves; untrained voices may have only a one-octave range. (*Culver Service*)

shorter than those of men, and women's voices are correspondingly higher. A soprano voice, usually possessed by a woman or a boy, is the highest pitched of human voices. [See Fig. 13–16.]

The strength or loudness of voice depends upon how much vibration is produced in the vocal cords. A shout requires much vibration and hence requires a forceful exhalation of air. A whisper, on the other hand, does not require much exhalation, and the final sounds are produced mostly by the tongue and the lips.

We enjoy the speaking or singing voice of certain persons because it has a special quality of smoothness or richness. Such a voice depends upon the production of overtones. A voice having good *timbre,* as it is called, may be natural or it may be developed by training in speaking or in singing. To speak or sing well, one must breathe properly, always having a reserve air supply in the lungs. One must also use correctly the spaces in the nose, the sinuses, and the throat when speaking or singing. Few throats need be tired by speaking, if the voice is correctly produced and developed.

The vowel sounds, *a, e, i, o,* and *u* are formed in the throat. The consonants are produced mostly by different positions of the tongue, lips, and teeth.

The voluntary and involuntary activities of the brain used in the learning of speech are complicated. We know that there are certain areas of the brain which govern speech. We also know that if a person is normally right-handed, his speech centers are found on the *left* side of the brain. If he is normally left-handed, his speech centers will then be on the *right* side of the brain. Many cases of speech difficulties have been produced by the attempt to make left-handed children use both the left and the right hand.

296. What care should be taken of the respiratory system? (*a*) Since the function of the respiratory system is to furnish oxygen for the body cells and to take out of the body carbon dioxide, it is important that there should not be

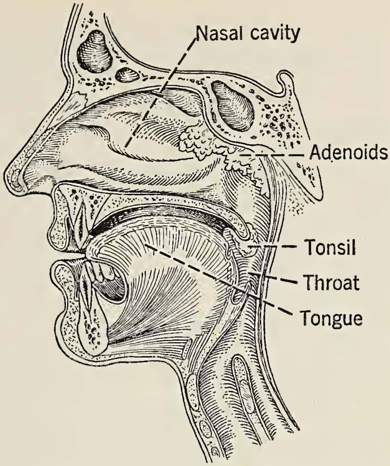


Fig. 13–17. In childhood, growths called adenoids sometimes develop where the nasal cavity opens into the throat. If allowed to remain, they cause mouth breathing and reduce efficiency. Their removal is a simple operation which if needed should not be postponed; otherwise serious illness may result.

mechanical hindrances to free movement of air in and out. In childhood, certain growths called *adenoids* may develop on the upper wall of the throat at the rear of the nasal cavity. [See Fig. 13–17.] These should be removed, because their enlargement will cause mouth breathing. They may also harbor germs and thus infect the ear, by means of the Eustachian tubes which connect the throat and the middle ear. A bony extension called a *spur* is sometimes present in the nose; this may interfere so much with the passage of air through the nose that the victim becomes a mouth breather unless the spur is removed.

b) It is equally important that every young person establish the habit of deep breathing. In ordinary breathing, the average person takes too little oxygen into his lungs. The one pint of air usually taken into the lungs at each inspiration is entirely inadequate for the proper exchange of oxygen and carbon dioxide. Headaches and drowsiness can be caused by shallow breathing, which may also make a person susceptible to disease.

c) Many individuals find that their mucous membranes are very sensitive to certain substances in the air, such as pollen from various plants or particles given off from feathers

of domestic fowl or hairs of cats, dogs, and horses. In those who are susceptible, or *allergic,* pollen produces a kind of inflammation of the nasal membranes resembling a cold. Hay fever is such an *allergy.* In some cases infection can be avoided by living during the pollen season in places where plants with the offending pollen do not grow. Medical scientists have in some cases successfully prepared *inoculations* made from pollen, hair, or feathers, and injected them under the skin of the victims. If the experiment is successful, artificial *immunity* will have been gained by the person, and he probably will have no further attacks for some time.

d) The common cold is one of the worst enemies of human beings. Colds are frequently the indirect *result of overeating.* They usually occur as a result of a run-down condition. An acid condition of the body usually accompanies a cold. Unfortunately there is no standard cure for colds, and there are almost as many remedies as there are individuals. Some remedies succeed with one person and fail with another, though a *liquid diet* of fruit juices and complete rest in bed may be advised by physicians. If an individual can train the body to expect and to enjoy moving currents of fresh air, an important preventive measure has been gained as a life habit. A constantly increasing number of persons who go without hats and who seek open-air conditions even indoors is a sign that fresh air in the form of a so-called draft is not always dangerous. During a cold, it is important never to blow both nostrils vigorously at the same time. The increased air pressure may force infected matter up through the Eustachian tubes into the middle ear.

e) One disease of the lungs that is both preventable and curable is *tuberculosis.* The death rate of this malady has been steadily falling since 1900. Yet it is still one of the greatest dangers to human beings. Dr. Logan Clendening, a noted authority, says, " Everyone gets tuberculosis at some time or other. Nine out of every ten human beings have had a tuberculous infection and have killed off the invader."

What about the tenth person, who did not kill off the invading germ of tuberculosis? He failed properly to interpret fatigue, a rise in body temperature in the afternoon, and a more or less continual cough. Also, through ignorance, carelessness, or necessity, he did not get enough rest, fresh air, and nutritious food. Tuberculosis in early stages is curable by such simple treatment, if continued long enough. The lung, if badly diseased, may sometimes be collapsed temporarily to permit it to rest and heal. But aside from this surgical device, no specific cures for tuberculosis, such as medicines or serums, have been discovered. The treatment is natural and reasonable. But it is of the greatest importance to discover the disease in its early stages, because the cure then is quick and sure. [See Fig. 13–18.]

297. Why do we ventilate our houses? Primitive men and savages had fresh air day and night because they never built windtight houses. Civilized man, on the other hand, with his modern fashions in building, violates many of the findings of science.

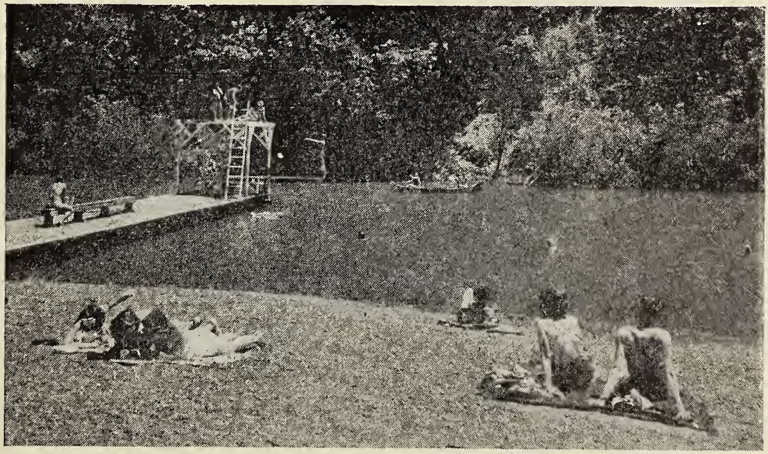


FIG. 13–18. Enjoyable exercise in the open air, sufficient sleep, nutritious food — whatever keeps the body in health — helps to prevent tuberculosis. (*From Monkmeyer*)

However, the large amount of disease in crowded, ill-ventilated places shows us the importance of following rules of health.

Man has had to learn that windows are not merely to let in light; that fresh air must constantly be brought indoors if human beings are to live and breathe there. At first, many persons thought it sufficient to have an opening by which fresh air could come in, now and then. Then they arranged openings so that the carbon dioxide could pass out. Now they know that so-called "poor air" in a room is due not so much to carbon dioxide and body poisons as it is to excessive water vapor in the air (too high humidity), or too little water vapor in the air (air that is too dry), coupled with a temperature that is too high. It is generally agreed that with

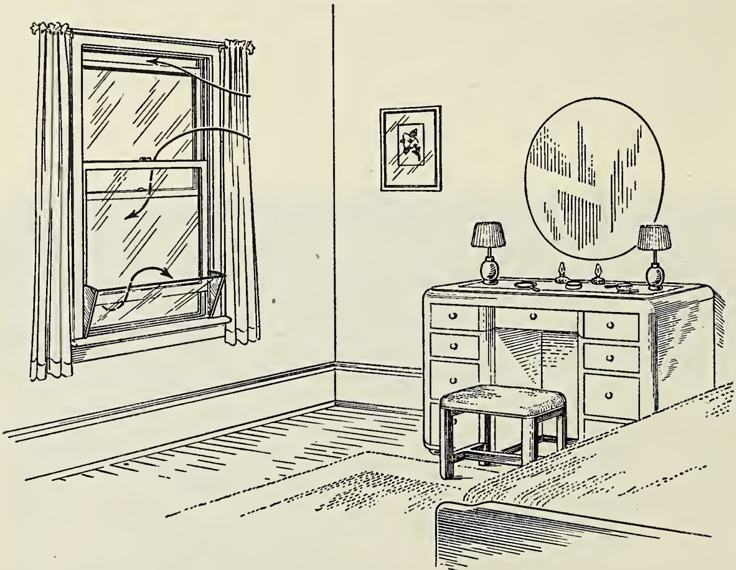


Fig. 13–19. It is as important to breathe fresh air at night as it is during the day. This is easily accomplished with but one window, opened at the top and at the bottom. Can you explain the air currents as indicated by the arrows? What is the advantage of the shield at the base of the window?

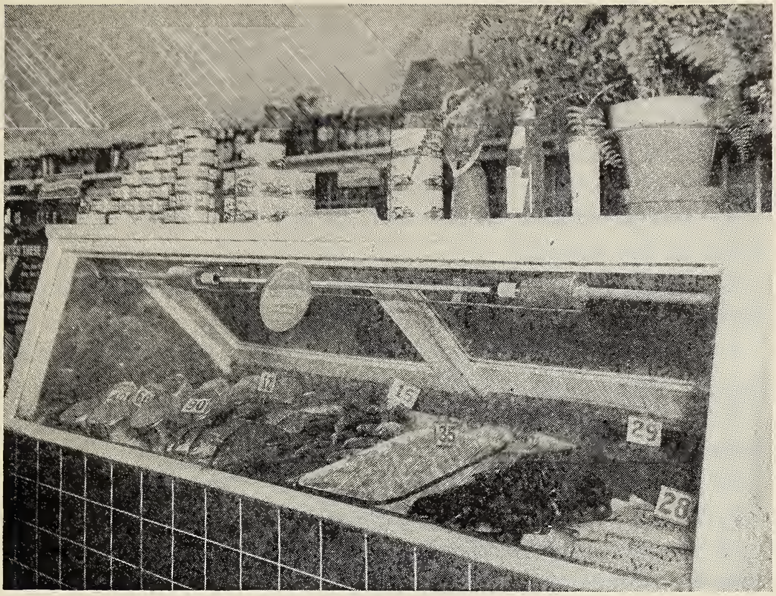


FIG. 13–20. The " Sterilamp " is used effectively in this modern food shop to help keep the food on display free from contamination. Can you suggest uses which are not mentioned here? (*Courtesy Westinghouse*)

proper humidity, room temperature need not be warmer than 68° F. during the colder part of the year. [See Fig. 13–19.]

298. What is sterilized air? There is now on the market a type of electric light called by the trade name "Sterilamp." Experimental use of this lamp shows that it quickly kills bacteria in the air or in substances near it. In certain hospitals, Sterilamps are used not only in operating rooms but in the forced-ventilation system, to *sterilize* the air — that is, to kill any living germs in it. [See Fig. 13–20.]

Questions

1. Is it true that dried, though living, seeds require oxygen?
2. What are some ways in which different vertebrates breathe?
3. What are the parts of the breathing system?
4. Of what value to us are the hairs and the mucous membrane found in the nostrils?
5. Can you trace the path of a particle of air coming from the atmosphere into an air sac of the lung?
6. What are cilia? Where are they found? Of what value are they to us?
7. Can you explain clearly why air goes into the lungs in inhalation?
8. What causes exhalation?
9. Why are both inhalation and exhalation necessary to health?
10. Explain the operation of the artificial lung, comparing it with the actions of the human lung.
11. What is the tidal air?
12. What is the residual air?
13. How can an individual increase his breathing capacity?
14. Of what value to an individual is the establishment of the habit of deep breathing?
15. What is the normal atmospheric pressure per square inch at sea level?
16. Can you name conditions where the atmospheric pressure is greater than this? Less than this? Explain your answer.
17. What precautions have to be exercised if men are to work in a caisson?
18. How do aviators provide against a decreased amount of oxygen at great heights above the earth?
19. How does oxygen get into the blood?
20. How does oxygen reach the cells?
21. Of what value is this oxygen in the cells?
22. How are the waste oxides that are formed in the cells excreted from the body?
23. Compare inhaled and exhaled air as to composition.

24. Compare the percentage of carbon dioxide in the exhaled breath with the percentage of carbon dioxide normally in the atmosphere. How much greater is the percentage of carbon dioxide in the exhaled breath?

25. Where and how is the voice formed?

26. What care should we take of the respiratory system?

27. Why should we ventilate our rooms day and night?

28. What is air conditioning?

29. What is the Sterilamp and how is it used to purify air?

Some things for you to do

1. Watch several different animals closely to observe their breathing movements. Typical animals might be an insect like the grasshopper, a snake (whose sides go in and out something like an accordion), a goldfish (note the alternate opening of the mouth and the gill covers), a frog (because this animal does not have ribs or diaphragm, he has to pump the air in and out of his nostrils by up and down movements of his throat), and the cat or dog, whose lungs and method of breathing are like our own.

2. Look at living cilia from the gill of a clam, under the microscope, mounted in some of the liquid from the interior of a clam.

3. What is your lung capacity as tested by a spirometer?

4. Test yourself to ascertain your average rate of breathing.

5. Get a lung at the butcher's and examine its structure to find bronchial tubes and air sacs.

6. Make a graph to show the constantly decreasing occurrence of tuberculosis.

7. Inspect the forced-ventilating plant of your school or some other building.

Think about these!

1. Have you any idea where your blood is made or how much blood there is in your body?
2. Can you explain what would be the probable result if your red blood cells suddenly all died?
3. If you climbed a mountain, would you have more red blood cells or fewer in your blood when you reached the top?
4. Why do you have a pulse in your arteries but not in your veins?

Words for this chapter

Circulatory system. The channels by which liquids and gases are moved from one place to another in living things; usually applied to the heart, blood vessels, and blood of animals.

Plasma (plăz′mȧ). The liquid part of the blood.

Corpuscle (kôr′pŭs·'l). A blood cell.

Hemorrhage (hĕm′ŏ·rĭj). Bleeding.

Fibrinogen (fī·brĭn′ō·jĕn). The liquid substance in the blood which, upon exposure to the air, produces a clot.

Fibrin (fī′brĭn). The material formed by fibrinogen in clotting.

Auricle (ô′rĭ·k'l). One of the two upper chambers of the heart.

Ventricle. One of the two lower chambers of the heart.

Aorta (å·ôr′tȧ). The largest artery in the body.

Groin. The region where the thigh joins the abdomen.

CHAPTER 14 ______________ UNIT 6

Why Are Blood and Lymph Important?

299. The blood streams are like canals. An ignorant traveler is once supposed to have turned back from the city of Venice in Italy because he thought they were having a flood there, not knowing that most of the streets in that strange city consist of canals. [See Fig. 14–1.]

If we could look down into our bodies and watch the activities of the living cells and tissues, we might recognize a considerable likeness between our bodies and the city of Venice. Certainly the method of distribution of food, oxygen, and waste materials by the blood vessels in our bodies would resemble very closely the commerce on the watery lanes of that ancient city. You already know that nearly two-thirds of the body of a dog or horse, or even of a human being, is water. So it should not surprise you to realize that the interior of the human body is wet, mostly with blood or lymph (both watery fluids). Even the bones are wet. There are many kinds of liquids in the body, but the most important

FIG. 14–1. In the strange city of Venice, watery lanes take the place of streets. Boats carry on the commerce. Like Venice, the human body is more watery than solid. The blood vessels are lanes through which food, oxygen, and wastes are distributed. (*De Cou from Galloway*)

fluid is the blood. The fact that blood will flow from a cut almost anywhere in or on the body shows how widely distributed this important liquid is. In the *circulatory system* of the average adult there are about six quarts of blood.

300. What do you see when you look at blood through the microscope? Let us put some blood under the microscope. We can then see many things we could not see before. Under a microscope the blood no longer appears red, but yellowish. You see many little things that look solid, like tiny pennies. These curious, rounded things, although an important part of the blood, are not liquid at all. They are

FIG. 14–2. Red blood cells have hemoglobin but no nucleus. White blood cells are larger, have a nucleus, but no hemoglobin.

the red blood cells. When seen as single cells they appear pale yellowish. Yet, when seen in masses of enormous numbers as they exist in the blood, the blood appears red instead of yellow. *In one drop of blood there are as many red blood cells as there are people living in the entire United States.* [See Fig. 14–2.]

Perhaps you will be fortunate enough to see one or more white blood cells. Each is whitish, larger than a red blood cell, and irregular in shape. But there are very few of them compared with the number of red blood cells. There are six hundred times as many red blood cells as there are white blood cells. Knowing this, can you tell how many white blood cells there are normally in a drop of blood? The white blood cells are made in the lymph glands and in bone marrow.

301. Of what solids and liquids is the blood composed? We have mentioned only solids in the blood. Actually the solids make up forty-five per cent of the blood. The rest of the blood is the liquid part called the *plasma.* This is nearly colorless and hence is not noticed so easily. The liquid that collects in a blister is mostly this colorless, liquid part of the blood.

The composition of the blood can be readily observed by whirling fresh blood, treated to prevent clotting. A tube of blood is rapidly spun around and around in a machine called a *centrifuge.* When the tube is removed, the blood will be found to have separated into two parts. Below is the mass of red and white blood cells, or *corpuscles;* while above is the clear liquid plasma, somewhat yellowish. Freshly drawn blood, if set aside in a bottle, will also separate like this in a short time.

Nine-tenths of this plasma is water, such as comes through the faucet at home, or flows in brooks in the woods. The remaining one-tenth is digested food and certain secretions, together with various wastes. Let us consider that the person whose blood is being studied had previously eaten a meat

sandwich. Some of this food, digested of course, would be a part of the plasma. Yet if you held the tube to the light, you would not find anything resembling either meat, bread, or butter. Can you tell why?

302. Is the number of red blood cells ever reduced? While the number of red blood cells in the body seems to be fairly uniform, it may be altered, either quickly or over a period of time. Sometimes the number of red blood cells in the body may be reduced in number by loss, as when there has been a loss of blood from a *hemorrhage*. Other causes, too, may produce a greatly lowered number of red blood cells. Such a condition may be brought about by a disease known as anemia (ă·nē′mĭ·*a*). Usually a diet somewhat richer in iron helps to increase the number of red blood cells. *Pernicious anemia* is a more serious disease in which the red blood cells are destroyed faster than they are manufactured. Recently scientists have made the discovery that the daily use of liver or liver extract in the diet cures this serious condition. Knowing the function of the red blood cells in the body, what do you think would be the physical problems of a patient suffering from this disease? What do you think would be the probable symptoms?

303. How can the number of red blood cells be increased? Not only may the number of red blood cells be lowered, but the numbers may also be quickly increased. It is interesting that if one climbs a mountain, ascends in an airplane or balloon, or engages in physical work, the red blood cells are greatly increased in number. [See Fig. 14–3.] This is partly due to the release of reserve red blood cells by the spleen, and partly to the more rapid manufacture of red blood cells by the red marrow of the ribs, vertebrae, and long bones of the arms and legs — the red blood cell factories of the body. Can you tell why the body would need more red blood cells under the conditions just mentioned?

304. How long do red blood cells live? The red blood cell lives from one to three months. During that time it

FIG. 14–3. Mountain climbing increases the work of the heart and requires more red blood cells. Why? (*Philip D. Gendreau*)

travels from one hundred to three hundred miles as it is pumped through the blood vessels by the beating of the heart. Old red blood cells, damaged beyond repair, are destroyed by large, white blood cells.

305. What causes blood to clot? Although nearly half of the blood consists of solids, it is so fluid in character that serious losses of blood would occur through continued bleeding, from injured blood vessels, except for a remarkable provision. Dissolved in the plasma is a substance called *fibrinogen.* When blood escapes from the blood vessels, as in a cut, this fibrinogen changes to solid threads of *fibrin.* If present in sufficient quantity, this plugs up the wound by forming a clot of blood, unless the blood is flowing too fast. Vitamin K is a valuable aid if the blood of a person is found to be deficient in fibrinogen.

If a small amount of freshly drawn blood is put into a bottle or a test tube, and left undisturbed, it will remain in liquid condition for only about seven minutes. Then it will clot

or jell because the fibrin has begun to form. If allowed to remain for about an hour, a yellowish fluid will be found around the clot. This is *serum.* It is blood plasma without the fibrin and red and white blood cells. Blood serum, taken from the blood of animals that have recovered from a certain disease, is frequently valuable in treating other animals and human beings suffering from that disease. [See Fig. 14–4.]

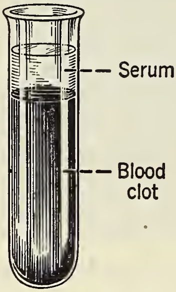


FIG. 14–4. If freshly drawn blood is let stand undisturbed in a test tube, it will normally begin to clot in about 7 minutes. After the clot has formed, a yellowish fluid called serum collects above it. The serum is really blood plasma without any fibrin or blood cells.

306. What is the use of hemoglobin? Perhaps the most important substance in the blood is the chemical called *hemoglobin,* which is found only in the red blood cells. This has an interesting story. Hemoglobin contains a great deal of iron – enough in the blood of the average man to make a small nail. You know that a nail or other piece of iron, if left in a damp place, soon becomes rusty. This rust is a new substance, the result of the combining of some of the oxygen of the air with some of the iron. The chemist would call this rust an oxide of iron. When the red blood cells come into the capillaries of the lungs, this hemoglobin of the red blood cells quickly unites with some of the oxygen brought into the air sacs when the person or animal takes in a breath. It does not form iron rust, but it does produce in the red blood cells a somewhat similar combination of iron and oxygen, a product called *oxyhemoglobin.* In this compound, the precious oxygen can be carried around the body and reach the most distant cells. The oxygen escapes to the cells, and the hemoglobin is carried back to the lungs for more

oxygen. When they return to the lungs, the red blood cells carry back some carbon dioxide. Blood containing a large quantity of oxygen combined with hemoglobin is colored bright red. Blood with little oxygen is a dark or dull red. [See Fig. 14–5.]

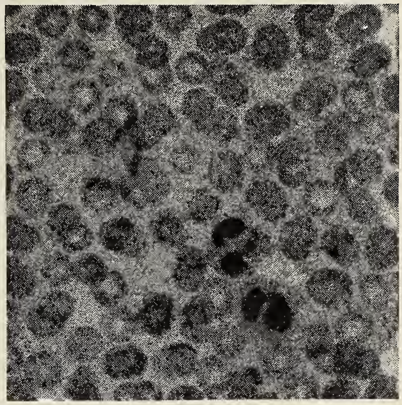


FIG. 14–5. This enlarged photograph of blood cells shows about 150 red blood cells and two prominent white blood cells. Can you tell the differences in structure and function between the red and the white blood cells? (*Julius Weber*)

Hemoglobin combines more readily with oxygen than does any other known substance. The watery part of the blood, the plasma, can absorb only very small quantities of oxygen. In fact, it takes 263 parts of plasma to absorb 1 part of oxygen. The same amount of hemoglobin will absorb 53 parts of oxygen. A person would have to have an enormous amount of blood — some 300 quarts — if the blood was only plasma and there were no red blood cells. This would call for such a huge heart, in order to pump the blood, that living as we do would be impossible.

307. **Do all animals have red blood?** One of the early and false ideas about the human body was that the air we inhale is carried over the body in little tubes. This sort of thing does happen in the case of the fly and other insects. But it never could happen in human beings. In 1616 an English scientist named Harvey discovered that there were indeed tubes in human bodies, and of different sizes, but that these tubes carried not air, but the red liquid called blood.

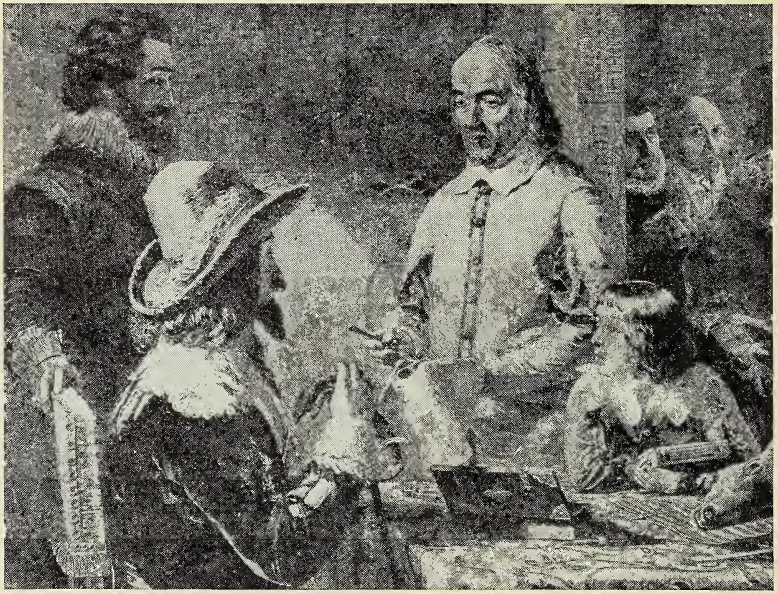


FIG. 14–6. William Harvey, the discoverer of the circulation of the blood, is showing blood vessels which he has dissected, probably from a deer. (*Ewing Galloway*)

[See Fig. 14–6.] Ever since his discovery, biologists have studied human beings and animals to find out just why they have to have blood. They found many animals, all of a low order, existing normally without any trace of blood. And they also found that in certain other low animals, such as the lobster and crab, the blood is colorless. In insects and worms, it may be greenish or yellowish.

308. Why do human beings require blood? Just why do we have blood? (*a*) Food has to be transported all over the body. Remember that food is never carried in solid particles. Digestion converts each nutrient into a clear liquid. When these liquid food particles pass into the blood from the intestinal wall, they are picked up and carried away in the blood current. Eventually, food is thus brought to all cells of the body.

b) Oxygen must reach every cell. When we breathe, we take air into the lungs. It is inside the body, yet its oxygen is of no value to us until brought to the cells. As you know, hemoglobin, the iron compound of the red blood cells, readily combines with the oxygen of the inhaled air. This union of oxygen and hemoglobin takes place in the capillaries of the lungs. Then these corpuscles move through the blood vessels, carrying their load of oxygen. When they reach the cells, the oxygen is given up.

Thus, the red blood cells are " messenger boys." Each one takes a supply of oxygen as it passes through the lungs, delivers it to another part of the body, where it is needed, and returns for another supply. The red marrow of the bones acts as an employment agency which keeps supplying the messenger boys to take the places of those that are crippled or broken down. The worn-out red blood cells, when they are no longer of any use to the body, go to the spleen or liver, where they are destroyed.

c) The waste substances made by living cells must be got rid of. Each body cell, whether bone, muscle, skin, or nerve, except the blood cells, is like an individual oyster which never moves from the place where it is attached. The cell can give off wastes where it is, but it cannot take the wastes to the outside of the body and drop them. It is the blood, again, which performs that task. Several kinds of waste materials are absorbed from the cells by the lymph, and then passed into the blood, which carries them to the liver. Here protein wastes are changed to urea. In the kidneys the blood gives off urea dissolved in the water of the plasma. Special tubes in the kidneys carry this urinary waste down into the bladder, from which it is passed off from the body as urine. The blood races on to the lungs again. Another important waste, carbon dioxide, is given up here, to be carried off from the body each time the person exhales air. Still other watery wastes are passed off from the skin in the form of perspiration. [See Fig. 14–7.]

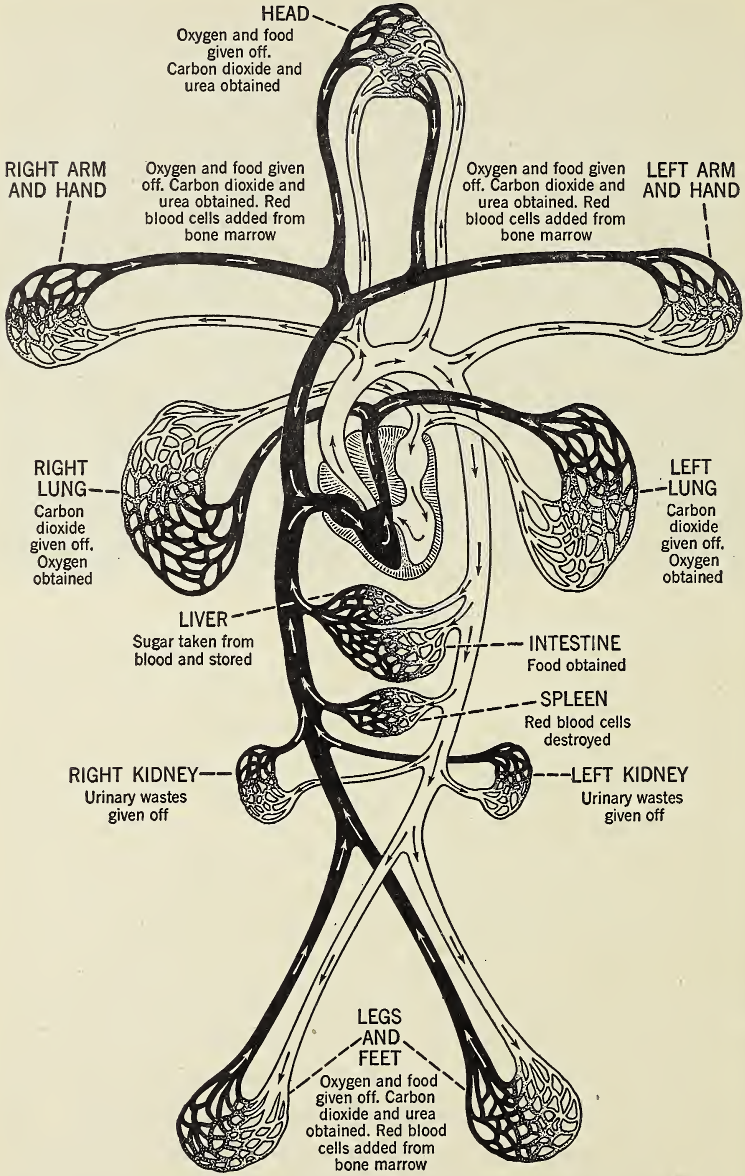


FIG. 14–7. Diagram to illustrate the circulation of blood throughout the body.

d) Body temperature is adjusted by the blood. If by exercising you become flushed and overheated, the blood helps to cool you off as it passes through the skin. All parts of the body (including hands and feet, which might get uncomfortably cold or even freeze in severe weather) are normally warmed by the blood, just as a house may be heated by hot water circulating throughout the building in pipes and radiators.

e) The blood is one of the main lines of defense for the health of the body. In the blood are large white blood cells that surround and feed on bacteria that may have got into the blood. There are also chemical substances in the blood, such as *antitoxins,* that destroy germs.

f) The blood picks up and carries around the body substances called hormones, secreted by the ductless glands. Although these glands have no outlet, the blood comes so close to them that their important secretions are readily absorbed by the blood through the walls of the very smallest capillaries. These hormones, which are necessary for growth and development, are then distributed throughout the body.

***309. What did William Harvey prove about the heart?** Every schoolboy today knows that blood moves or circulates through the body. He knows, too, that the heart is the pump which causes this ceaseless flow of the blood. [See Fig. 14–8.] These facts have been accepted, however, for only about three hundred years, since Harvey discovered how the blood circulated. Before that, men had thought that the blood in the blood vessels moved in first one direction, then in the other direction.

Harvey was the first man to prove that:

a) The heart beats by contracting and then expanding.

b) The blood vessels do not contract as the heart does.

c) The heart pumps the blood to different parts of the body.

d) The blood passes through the lungs on its way from the right side of the heart to the left side of the heart.

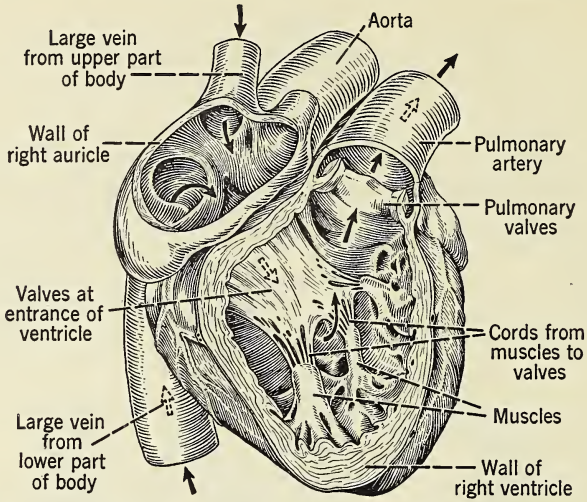


FIG. 14–8. The outer walls of the right auricle and of the right ventricle of this human heart have been cut away. Note the two large veins entering the right auricle. Note also the valves between the right auricle and the right ventricle. Find other valves. What heart chambers are not shown?

e) Most of the blood pumped out of the heart returns to it by way of the *veins.*

Important as the blood is in a healthy living body, it would be of no use if it did not move through the body. If the blood were suddenly to stop moving, wastes would almost immediately poison the system, cells would suffocate for lack of oxygen, or perish for want of food, and hands and feet might get so cold that their cells would die.

Everyone today knows that the heart is the pump that keeps the blood stream moving. Just how it works, and just how the blood goes on and on in an apparently endless moving belt through tubes of all sizes, is the story that is now to be told.

310. **What is the pump for the blood?** The heart has long been regarded by most persons as the seat of life. Ancient warriors felt that they would be stronger and braver if

they ate the hearts of their enemies. It is much more accurate to think of the heart as one of the most important organs of the body. Certainly no organ is more faithful in doing its allotted work, day and night, throughout one's lifetime.

A human heart is about as large as the owner's clenched fist. It is located directly behind the breast bone with the point of the heart downward and somewhat to the left. It is a true pumping engine, provided with valves and four chambers. This does not mean that it exactly resembles a four-cylinder automobile engine, all of whose pistons are working together to cause a single shaft to turn. Yet the heart may, in some ways, be compared to such an engine. Two of the four chambers of the heart receive the blood flowing into them from the rest of the body. They are the *auricles*, each located in the upper part of the heart, one on the right and the other on the left. The heart is divided by a wall of muscle into right and left halves. Each auricle passes blood down into the *ventricle* of its side.

The other two chambers are the true pumping chambers. They are the ventricles, and they are located in the lower part of the heart. The right ventricle is directly below the right auricle. The left ventricle is similarly directly below the left auricle. The heart is almost entirely composed of muscle. The ventricles in particular have greatly thickened walls, because their work is to force the blood out of the heart. The blood from the right ventricle goes to the lungs, and the blood from the left ventricle goes out to all other parts of the body. Which ventricle do you think would require the thicker walls of muscle?

311. What are the arteries? The *arteries* are the large, thick-walled blood vessels into which the blood passes from the heart. Through the arteries, the blood moves all over the body. The *aorta* is the largest artery. It carries blood downward from the left ventricle to the trunk and the legs. Branches go to the arms and to the head. The *pulmonary*

(pŭl′mō·nĕr′ĭ) artery carries blood from the right ventricle to the lungs. This artery is the only one to carry dark-colored blood. Such blood contains little or no oxygen and much carbon dioxide. Can you tell why there is so little oxygen in this blood? All the other arteries carry bright-red blood. Such blood contains much oxygen. Can you explain the presence of so much oxygen? [See Fig. 14–9.]

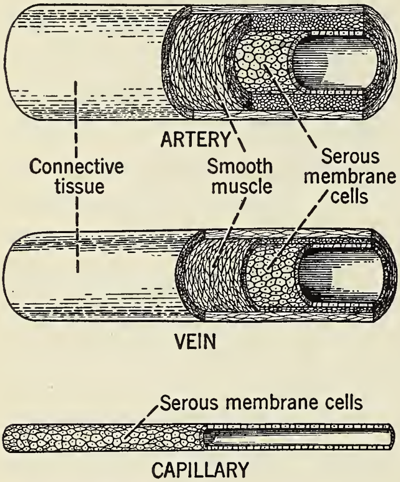


Fig. 14–9. The differences in structure of the three kinds of blood vessels can be understood from these diagrams. The artery and vein both are lined with a very thin membrane called a *serous* membrane. The capillary is composed of such cells only. The artery and the vein have a thick outer wall and a middle muscular wall.

The walls of arteries are quite elastic. They can stretch when more blood is pushed into them by the contraction of the heart. One of the layers in the wall of an artery is composed of muscle fibres. When these contract, they shut off the supply of blood. Sudden fear may cause the face to become pale. The reason is that strong emotion has interrupted normal functioning, and the blood supply to the small arteries of the face is temporarily cut down. Fainting usually is caused by lack of a sufficient supply of blood to the brain. This may be caused by a physical or emotional disturbance. A person who has fainted should be placed flat on his back until the blood again flows to his brain.

312. What causes the pulse? At each contraction of the strong-walled left ventricle, a great wave of blood is pushed

out into the aorta, and into all of its branches. This extra quantity of blood stretches the arteries enough to be noticeable at places where the arteries are fairly near to the surface. This wave of blood felt in an artery is called the pulse. The pulse rate of normal adults is between 65 and 80 beats per minute. It is much over 100 when one is exercising, and less than 70 when he is lying down. Can you see any reason why the pulse rate should change as it does?

313. **Do capillaries have a pulse?** The smallest arteries, each about the size of a hair, finally divide into the smallest blood vessels of the body, the capillaries. These tubes are so small that they cannot be seen except under a microscope. Capillaries are in all living parts of the body. Most of the bleeding from surface wounds comes from cut or broken capillaries. Capillaries do not have a pulse because they are too small to receive the wave of blood.

314. **Of what importance are the veins?** The capillaries connect the arteries and the veins. It is the veins that carry the blood back to the heart. Since there is no pulse in the capillaries, there can be none in the veins. Can you explain this? Through the veins the blood flows steadily back to the heart. The walls of the veins are thinner than those of the arteries, lacking strong muscles. In the larger veins there are valves, which prevent any backward flow of blood, and thus aid its passage toward the heart. These valves can easily be found on the back of the hand of any adult person

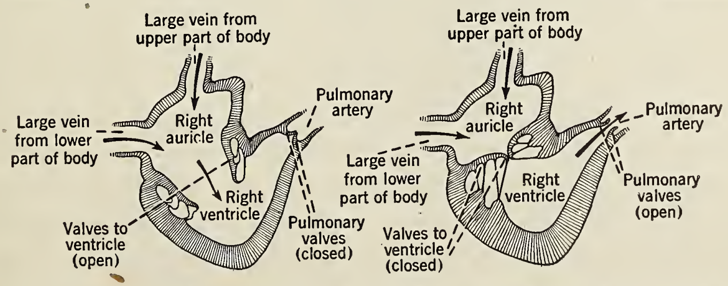


FIG. 14–10. Blood from the body flows into the right side of the heart. Can you explain the actions indicated here?

whose veins are rather noticeable. Place the end of one finger firmly on one of the long veins. Then with a second finger press along the vein an inch or so in the direction of the wrist, and remove this second finger, keeping the first one in place. The blood will be forced forward out of the vein, and that part of the vein will flatten. Blood cannot back up into the vein because of the valves. Releasing the first finger will cause the vein to take its full size again. [See Fig. 14–10.]

*315. **What would be the path of a drop of blood in moving through the body?** Suppose that we start with blood entering the right auricle. From here it descends to the right ventricle. The walls of the ventricle contract and push it out into the pulmonary artery, which divides, thus carrying the blood into both lungs. Here the blood gives up its load of carbon dioxide and some water, and its red blood cells take on a load of oxygen. Without pausing, the blood moves on through the pulmonary vein and enters the left auricle. Then it is forced down into the left ventricle, from which it is sent out by the contraction of the muscular ventricle walls into the great aorta. Branches of the aorta carry blood to every part of the body. A special branch, extending to the intestine, picks up digested food. Thus arterial blood is rich in food. In addition, it is bright red from oxygen carried in the red blood cells. The one exception, as has already been pointed out, is the pulmonary artery, the blood of which has practically no oxygen. Arterial blood also contains urea, a waste which it gives off when passing through the kidneys. The veins bring blood back to the heart from all parts of the body. Blood in the veins, except in the pulmonary vein, is dark red, since it contains little or no oxygen.

*316. **How fast does the blood move?** How long does it take for a blood corpuscle to make the circuit of the body? Its speed varies in different parts of the organism. In the aorta it travels about one to two feet a second, but its rate is slowed down as it gets into smaller and smaller blood vessels.

In the capillaries blood moves about one foot in a minute. So a blood cell in traveling over the body will take at least one or two minutes to return to the starting point.

317. How is lymph related to blood? Feel a piece of beefsteak. You find moisture on your hand. It is not red; so it is not blood. It is true that this moisture is mostly water; yet we do not call it water. It is the most watery part of the blood plasma, called lymph. It resembles blood serum. Do you remember the colorless, sticky fluid that collects under a blister and which escapes when the blister is opened? That too is mostly lymph.

Lymph is very important in the body. When blood is passing through capillaries, water, digested food, and oxy-

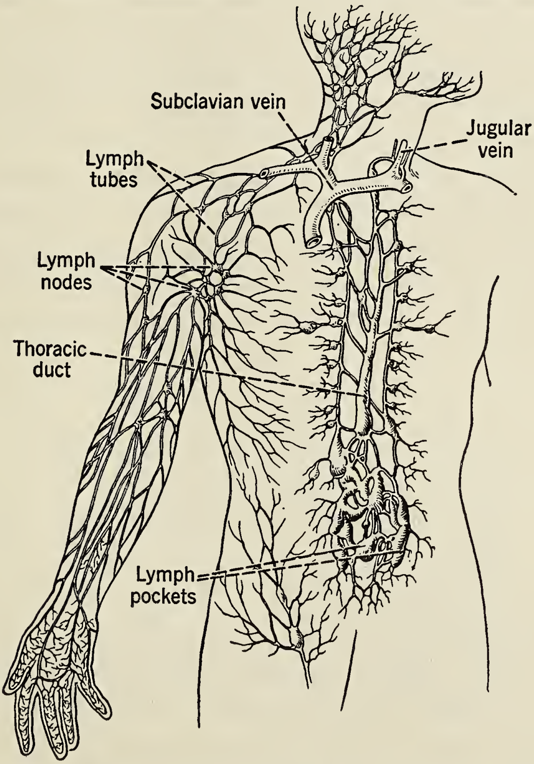


FIG. 14–11. The lymphatics help the body in many ways.

gen escape. Their destination is the body cells, but they do not pass directly into the surrounding cells. Instead, they become part of the lymph which is in between the cells of the body. From this lymph the cells absorb oxygen and such nutrients as they need. Also these cells pass off their wastes into the lymph instead of into the blood. It is difficult for these watery wastes to get back directly into the capillaries. So they remain in the lymph in the spaces between the cells. But these wastes must be removed. If the capillaries cannot collect the wastes, how are they to be excreted?

318. What is the lymphatic system? The lymph tubes or lymphatics make the removal of such wastes possible. The spaces surrounding the cells are filled with lymph. From them extend small lymphatic tubes looking something like capillaries. In fact these tubes extend all over the body like a second circulatory system. Since lymph flows through them, they are called the lymphatic system. [See Figs. 14–11 and 14–12.]

The lymph enters these lymphatic tubes. It is moved forward whenever these tubes are squeezed. This occurs when you contract your muscles as you do in exercising, when you breathe, or move, or when you are massaged. The lymph might be squeezed backward into the cell spaces except for

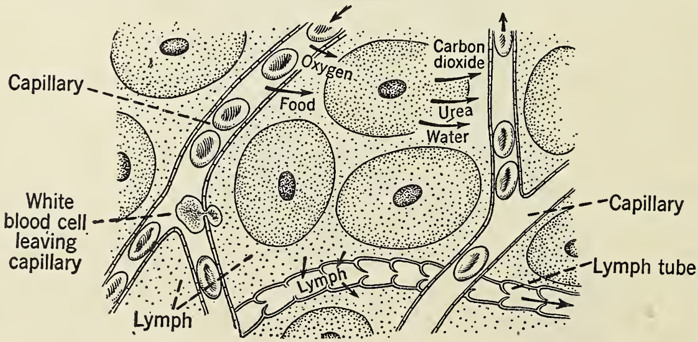


Fig. 14–12. This is a biological puzzle picture. Can you explain each structure and action indicated?

valves like those in the veins. These prevent backward flow. Since no heart pumps the lymph, it does not have any pulse. It also moves very slowly. Moderate rhythmic exercise, such as walking, dancing, skating, or massage, is very valuable in assisting the movement of lymph through the body.

*319. **What is the thoracic duct and what passes through it?** The lymphatic tubes of the right arm, right shoulder, and right side of the head empty into the *right sub-clavian* vein in the neck. All the other lymphatic tubes of the body finally unite in one large vessel called the *thoracic duct*. This extends from the abdomen up through the diaphragm into the chest cavity. It joins the *left sub-clavian* vein in the left side of the neck. Here most of the lymph is poured into the blood stream. Lymph in the tissues is similar to blood without red blood cells and with less digested food. The lymph that is discharged into these two big veins contains most of the waste material, especially water, carbon dioxide, and urea. In addition the lymph in the thoracic duct is very much richer in digested fats. As you will recall from Chapter 12, while the digested food is passing through the intestine, the digested fats are absorbed by the lymph vessels which pass them directly into the thoracic duct. The first place, then, that the digested fat of butter, for instance, gets into the blood is in the neck and not the intestine. The waste substances in the lymph, which are now in the blood stream, will be passed off from the body by the excretory organs. The lungs excrete carbon dioxide and some water. The skin passes off water with some wastes in the form of perspiration. The kidneys take water and urea from the blood, and pass this waste as urine down into the bladder from which it is excreted from the body.

320. **Why are lymph glands and nodes valuable to us?** In addition to lymph tubes, there are *lymph nodes*. These are swellings through which all the lymph must pass. Lymph nodes are located in the arm pits, near the elbows, on the sides of the neck and in the *groin* where the thigh

joins the abdomen. They feel like rounded, hard objects.

Lymph nodes are valuable in maintaining good bodily health. They act like sieves in straining out bacteria or other foreign substances in the lymph. But more important, they are garrisons containing white blood cells. When there is an infection, such as a boil, in which many invading bacteria are battling against white blood cells, some of the injurious bacteria are likely to be carried in the lymph to the nearest lymph node. [See Fig. 14–13.] Here the battle may con-

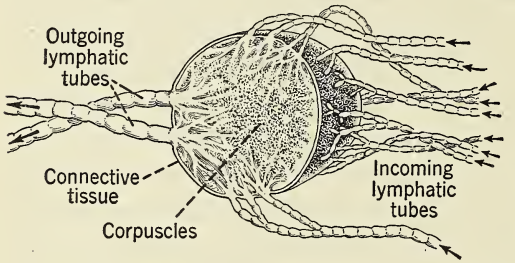


Fig. 14–13. A lymph node is a kind of fort, garrisoned by an army of white blood cells. Here is a lymph node shown in cross section.

tinue. The victim realizes this by the swelling and soreness of these lymph nodes. Usually the bacteria are soon devoured by the white blood cells, the soreness disappears, and the swelling goes down. Lymph nodes thus help to ward off disease.

321. **What can be done to safeguard the circulatory system and the lymphatic system?** (*a*) The deficiency disease, anemia, has already been referred to earlier in this chapter. It is easier to prevent this trouble than to cure it. Anemia is usually caused by incorrect diet, infectious diseases, diseases of the bones and kidneys, overwork, or worry, any of which may cause a lowered number of red blood cells and correspondingly a lessened amount of hemoglobin.

In treating or preventing anemia, the diet should first be considered. Vegetables such as spinach, beet greens, and lettuce; egg yolk; fruits; and, especially, beef and liver are all excellent foods. Outdoor life, with as much sunshine as possible, is valuable, as are vitamins A and B.

b) *Malaria* is a disease of the blood, which is common in tropical and temperate regions of the earth. It was first thought to be due to bad air, hence the name *mal-aria, mal* meaning *bad,* and *aria* meaning *air.* However, it is now recognized that the air is not a cause of malaria. The disease is caused by the bite of a female Anopheles mosquito, which has previously bitten a malaria patient. The mosquito has sucked up malarial organisms, or spores, with the blood of the victim. In the body of the mosquito these organisms reproduced, forming many spores; some of these were injected into the new victim when the mosquito bit him.

In the human blood these malarial spores enter red blood cells, breaking them down and forming new spores by reproducing. The release of these spores and certain poisons into the blood causes a chill, followed by a fever. Until controlled by quinine or some other means, the spores continue to multiply and attack new red blood cells.

c) There is a widespread opinion that one can have impure blood which can be purified. This idea has been helped by patent-medicine advertising in cheap papers and magazines, and to some extent over the radio. Many persons think that when pimples and boils appear, the blood is bringing its impurities to the surface and thus getting rid of them through the skin. Such eruptions of the skin are usually caused by pus germs getting into the skin along a hair or through a tiny cut or break in the skin. Science says that there is no blood purifier. Sulfur and molasses, which were once widely used as a springtime remedy, are of no value whatsoever. The sulfur is not soluble in the body and the molasses is only a very low-grade form of sugar. Good blood is largely the result of regular attention to diet and normal living.

d) Blood transfusions are given when, through disease or hemorrhage, the amount of blood has dropped or the quality of blood in a patient has decreased. *Donors,* or givers, of blood, have to have their blood tested to make sure that

it is of the right group, or kind similar to that of the patient. There are four groups. The donor usually gives about a pint and may receive about fifty dollars for the service.

e) Many persons take headache pills or other remedies because they are advertised as a quick relief. They are ignorant of the fact that many of these so-called remedies are strong drugs and that they will help the headache only by reducing the amount of blood sent to the brain. Whatever remedy is found to help, such as heat, rest, and so on, it is certainly important to analyze the situation and to find out the cause of the headache in order to avoid its repetition.

f) *Blood poisoning* is a very serious condition produced by the uncontrolled development of certain dangerous bacteria. It may result in either infection in the blood, or, more often, infection in the lymphatics. It may start from careless picking of a pimple with a finger nail. If the white blood cells in the blood and the lymphatics are unable to defeat the germs by surrounding them and eating them, then the invading organisms will multiply. The infection or inflammation is said to have spread. Such infection usually follows a lymph tube. If the bacteria overpower the white blood cells in a lymph node and get intrenched in the node, it may be difficult to get rid of them and re-establish health. However, reinforcements of new white blood cells continue to battle the germs and generally win. Health is the normal condition, and the body always tends to right itself. If everyone would attend to all wounds, even small cuts, by promptly treating them with iodine or some other good antiseptic, then using sterilized dressings, or bandages, until they have healed, blood poisoning would be rare.

g) The valves of the heart can be injured permanently by bacteria in the blood or by poisons from an infected region in the body. Young persons, especially, should know that diseased tonsils and tooth abscesses, if neglected, can cause serious heart trouble. Diphtheria and rheumatic fever are also possible causes.

h) Life-insurance companies are careful to check for high blood pressure and possible heart trouble among applicants for insurance. Heart disease as a cause of death is increasing. This fact may be due in part to the strain of modern living. Temperate living means more happiness and a longer life.

QUESTIONS

1. Why is the blood considered to be the most important liquid in the body?
2. About how much blood has an adult?
3. What can one see if a drop of blood is put under the microscope?
4. What is the composition of the blood?
5. Could you distinguish between blood plasma and blood serum?
6. How do fibrinogen and fibrin differ?
7. Where are red blood cells made?
8. Where are white blood cells made?
9. What are the functions of the blood cells?
10. What may cause a reduction in the number of red corpuscles in an individual?
11. What can cause an increase in the number of red corpuscles in an individual?
12. How long does a red blood cell live?
13. What causes blood to clot and why is clotting so important?
14. What is hemoglobin, and what does it do?
15. What functions are performed by the blood?
16. Who discovered the true circulation of the blood? When?
17. Describe the heart and tell how it acts as a pump.
18. Compare an artery, a vein, and a capillary as to structure.
19. Can you trace the path of a drop of blood as it travels through the body?
20. How fast does the blood move in the human body?
21. What suggestions can you make towards safeguarding the circulatory system?

22. How would you define *lymph*?
23. Where is lymph formed?
24. Why is lymph so important in the body?
25. What is the structure of a lymph tube?
26. What takes the place of a heart to force the lymph through the lymph tubes?
27. What is the thoracic duct?
28. What flows through this duct in addition to lymph?
29. Where are lymph nodes located in the body?
30. Why are lymph nodes valuable for the maintenance of good health?

Some things for you to do

1. Take your pulse rate per minute when standing, sitting, and lying down, and after exercising.
2. Get the pulse rate per minute of several other persons of about your own age, and of an equal number of older adults. Can you draw any conclusions from the facts you have gathered?
3. Examine some human blood under the microscope, and try to distinguish between the two kinds of blood cells.
4. Examine some red blood cells of a frog and note the nucleus.
5. Read about the characteristics of the blood of lower animals, and then write a short composition on this subject.
6. Find out all you can about Harvey and how he came to discover the facts about the circulation of blood.
7. The frog has lymph hearts that beat. The next time you have a chance to examine a live or a freshly killed frog, look for these small, pulsating organs, located on either side of the middle, at the extreme rear of the back.
8. Under the microscope look at some lymph from a blister, and see if you can discover some white blood cells in it.

Our Bodies Are Controlled By Means of a Network of Nerves

BIRDS, as you know, have keener sight than man; and owls can hear more delicate sounds than any man can hear. But in touch, and in capacity to enjoy taste, man is probably unsurpassed by any of the animals.

Unit 7 will show how the combination of an extraordinary brain and special senses gives man the advantage he has in living. His brain directs the use that he makes of his senses. He can remedy their shortcomings. When his sight is limited, he can use glasses; when he cannot hear over great enough distances, he can use the telephone. When a distance is too long to be covered on foot, he has a wide choice of mechanical conveyances to help him.

The brain itself, the seat of man's intelligence, is a built-in telephone system by means of which millions of nerve fibers carry messages through the body and produce co-ordination.

Yet despite his intelligence, man sometimes harms his nerv-

ous system and weakens his physical and mental ability by using drugs and narcotics. It is hard to understand why a being with such abilities should willingly spoil or destroy them.

Think about these!

1. Can you believe the statement that there are 12,000,000,000 nerve cells in the brain?
2. What keeps the heart beating and the lungs breathing?
3. Is it true that a diet of fish is good for the nervous system?

Words for this chapter

Nerves. Whitish cords made up of nerve fibers, by means of which nerve impulses or messages are carried between the various body parts.

Reflex (rē′flĕks) action. Action in which the spinal cord instead of the brain is the instrument causing a response in muscles or in glands.

Ventral. The region of an animal opposite to the dorsal; usually situated on the lower side.

Dorsal. Situated on, or near, the back. The dorsal region of animals is usually uppermost.

Cortex. In the brain, the thin outer layer of brain cells, called the *gray matter.*

Neuron (nū′rŏn). A nerve cell.

Dendrite (dĕn′drīt). A fibrous extension of a nerve cell, through which impulses enter the cell body.

Axon (ăk′sŏn). A fibrous extension of a nerve cell, through which impulses leave the cell body.

Neurosis (nů·rō′sĭs). A breakdown, often temporary, of the nervous system.

CHAPTER 15 ——————— UNIT 7

What Messages Do Our Nerves Carry?

322. How important is the nervous system to an individual? The nervous system is without doubt the most important of all the internal systems of your body. Without it, you would no longer be a human being, for you would be a mere lump of unfeeling matter, entirely without your present personality and more useless than a clod of earth. All your contacts with the surrounding world which result in your reactions of pleasure and pain, and all your conscious acts, are made possible by your brain and *nerves*.

The human body has more cells in it than there are people in the entire world. These cells are, in many instances, at some distance from each other. Most cells cannot move about. Therefore messages must be sent from one part of this community of millions and millions of cells to the other parts, so that all regions of the body will work together smoothly and harmoniously. The nervous system brings about just such co-ordination.

The nerves have been compared to telephone cables that

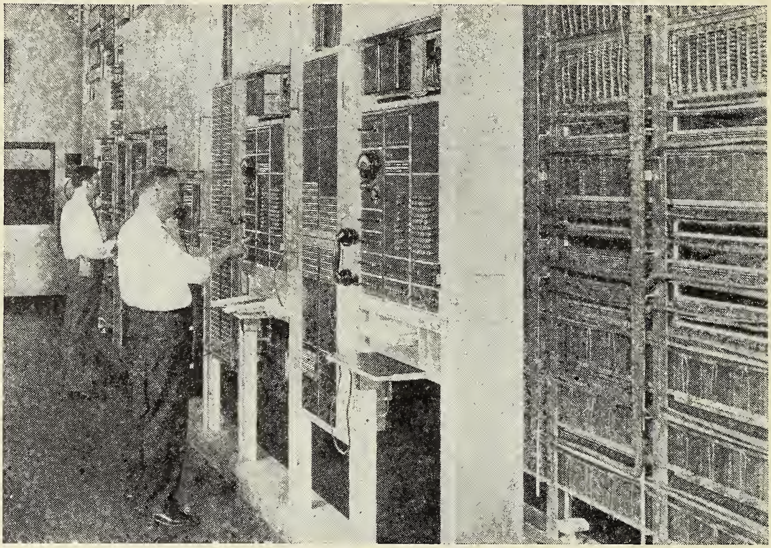


Fig. 15–1. The maintenance room of one of the dial telephone systems in New York City might be called the " nerve center " of that central office. (*Courtesy New York Telephone Co.*)

carry their messages from one place to another. Just as the telephone company has a main office called " central," so the nervous system has the brain which is the clearing house or " central " for the body. [See Fig. 15–1.] Knots of nerve tissue, called *ganglia* (găng′lĭ·*ȧ*), are found along the spinal cord and elsewhere in the body. Each of these corresponds to an automatic telephone station.

If you want to make a telephone call to someone many miles away, you pick up your phone and ask for " long distance." The central office of the telephone company answers, and sends your call through. In a similar manner, your eyes see a car coming toward you as you start across the street, the message goes to your brain, the " central office " of your nervous system, and the call is put through to your leg muscles to stop your forward motion.

But if you wish to make a local call, you do not call the central office. You dial the call and this puts your call di-

rectly through the electrical apparatus which connects you automatically. Similarly, if you should put your hand on a hot object, the "call," or impulse, goes through an automatic "local office" of nerve tissue, that is, a ganglion, in the spinal cord. A message is sent out to your muscles and your hand is moved away quickly by *reflex action,* not by planned thinking. The "call" does not have to go through your "central office." It is done automatically.

*323. **What kind of nervous systems do other animals have?** There are a few animals that do not possess any kind of nervous system. All other animals have a nervous system, either simple or more complex. The starfish, for instance, has one of the simplest of nervous systems. It consists of a nerve lying along the underside of each of the five rays. All these five nerves are connected by a nerve ring around the mouth at the base of the rays. Such an animal has no brain.

A higher type of nervous system is seen in the common earthworm. Here, in the head end, there is a small lump, the brain. From this two nerves emerge, making a sort of collar; they unite on the underside in another lump, or ganglion. The rest of the system consists of a nerve extending

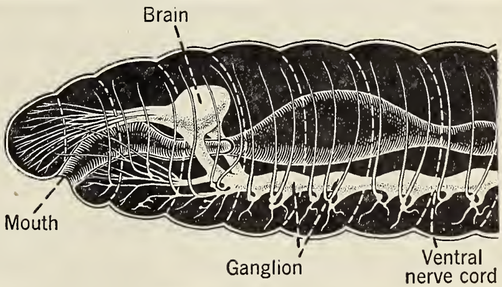


Fig. 15–2. The earthworm has one of the most simple of all nervous systems.

along the lower part of the body, with a ganglion in each division of the body, from which tiny nerves branch off. [See Fig. 15–2.]

Vertebrate animals, that is, animals possessing a spinal column or backbone, have the highest type of nervous systems. Fishes, frogs, snakes, birds, and mammals, and human be-

ings, are vertebrates. They all possess brains increasing in size and complexity from fishes to mammals. Man's brain, in proportion to his size, is largest and most complex of all.

In all vertebrates, from the lower side of the brain there extends a large nerve, the *spinal cord.* Instead of being on the underside, or *ventral* region, as in the earthworm and most of the other invertebrates, this main nerve is in the back, or *dorsal* region. It is protected by being enclosed in a series of hollow bones called the *spinal column.* Many pairs of nerves, called *spinal nerves,* branch off from the spinal cord. Important nerves, called the *cranial* (krā′nĭ·ăl) *nerves,* branch off from the brain. In the higher vertebrates, there are also nerves among the internal organs which make up the *autonomic nervous system.*

324. The human nervous system. The human nervous system is similar to that of the dog or any other mammal, but it is larger and more complex. The human brain is from two-and-a-half to three times as large as the brain of any other mammal. We have a central nervous system, consisting of the spinal cord and most of the brain. To these are connected nerves that reach throughout the body. We also have an autonomic nervous system, made up of several long cords with many nerves and some groups of connections in the internal parts of the body. Each of these masses of connections is called a *plexus.* Every part of the body is reached by nerves; a message or impulse may be received from, or sent to, any part of the body.

325. Why is the brain the most important part of the nervous system? The "central office" of the nervous system, and probably the most important organ in the body, is the *brain.* This is the special organ through which our physical and mental life is ordered. Man, because of his superior mind and physical brain, can compete with nature, outwit the animals, and overcome obstacles that few other creatures can surmount. Man's brain has three main divisions: the *cerebrum* (sĕr′ē·brŭm), the *cerebellum* (sĕr′ē·bĕl′ŭm), and

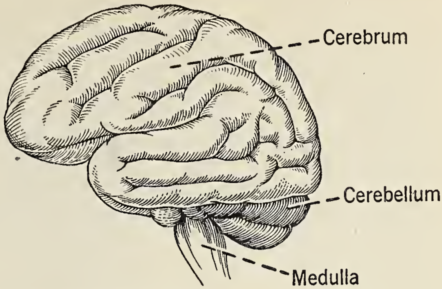


Fig. 15–3. The brain has three parts: the cerebrum, the cerebellum, and the medulla.

the *medulla* (mē·dŭl′ȧ). [See Fig. 15–3.] The brain is completely enclosed within the bones of the skull, which since early babyhood have grown together, forming a complete bony case like a solid shell. There is no way of getting to the brain itself during childhood and the rest of life, except by actually sawing through the skull bones. This is done by surgeons when they have to operate on the brain. The brain is also covered by three layers of membrane, which protect it and support the blood vessels and nerves attached to the brain.

326. The cerebrum. The largest division of the brain is the cerebrum, or brain proper. It fills most of the skull in front and at the top. It is shaped somewhat like the meat of a large English walnut; it is wrinkled, and is divided into halves called *hemispheres*.

On the outside of the brain is a thin layer of gray nerve tissue. The tissue inside the brain is white and very soft. The gray matter is called the *cortex*, and is believed to be the part concerned with *thinking*.

The folds or wrinkles are deeper in man's brain than in the brain of any other living creature. This makes possible a greater amount of cortex, the most important part of the brain. [See Fig. 15–4.]

If the brain were smooth, like that of the fish or the frog, the amount of cortex which man now has could be obtained only by enormously increasing the size of the brain. This

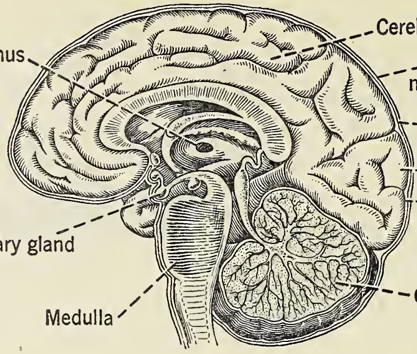


FIG. 15–4. The human brain as seen in a vertical section.

would, in turn, require a correspondingly enlarged head. In fact it might well call for a head two or three times as large as that we have now. This would be more than awkward. But by possessing many little folds, man can gain a large amount of cortex in relation to the size of his head. Since the cortex contains the most important nerve cells, man's brain, by possessing more cortex than the brains of the animals, contains more of these important nerve cells. It is therefore a brain much superior to that of any other living creature.

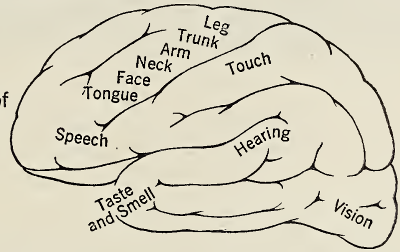
The cerebrum in man is the center of intelligence, will, memory, and the emotions. This does not necessarily mean that the brain *starts* mental activity. It is more accurate to think of the brain as the unintelligent instrument of the intelligent mind. Just how the mind and brain work together is the greatest puzzle of biology. Today, with the brain that he is born with, and the opportunities later for developing it, a human being has a better chance than ever before to understand and control his environment.

Man's possession of this superior nervous system does not mean that he will always use it to the highest degree. If he fails to make the best use of it, his failure is often caused by bad habits such as laziness, carelessness, and the use of harmful stimulants and drugs.

Modern surgery and experimental evidence have shown that the *right* side of the cerebrum governs the voluntary actions of the muscles of the *left* side of the body. Similarly the muscles and nerves of the *right* side of the body are connected with the *left* side of the brain. Areas in the brain that are definitely concerned with certain parts of the body have been mapped out. Knowledge of this is of value to the surgeon who operates on the brain to remove a blood clot or a growth, the presence of which was indicated by the paralysis of a part of the body. [See Fig. 15–5.]

FIG. 15–5. In the cerebrum, special parts are concerned with bodily regions and actions.

Front of brain



Rear of brain

327. The cerebellum. The cerebellum, or little brain, is located below the cerebrum and at the rear of the skull. It is relatively small and is not divided into hemispheres. Its surface is covered with *transverse* ridges, or ridges extending crosswise, and it is composed of both gray and white matter. Through experiment and the study of diseased animals and persons, it has been shown to be the center for harmonizing muscular action in the body. For example, it is believed that the cerebellum makes possible carrying on at the same time such complicated and different muscular activities as walking, holding packages, and carrying on a conversation while looking ahead down the road one is traveling. Without the cerebellum, one might be able to move different muscles, but he would not be able to use muscles together harmoniously in order to operate a typewriter or to play the piano. By means of the cerebrum a person carries out his desire or his determination to play a game of baseball. It

Fig. 15–6. In each boy, many bones and muscles must work together in the race. But such co-ordination depends upon a healthy cerebellum. (*Courtesy Evanston Township High School*)

is his cerebellum, however, by means of which he co-ordinates muscular movements such as seeing, throwing, shouting, and running. [See Fig. 15–6.]

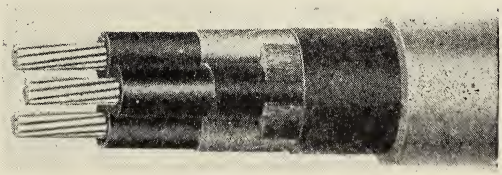
328. The medulla. The medulla is still smaller than the cerebellum and is located at the very base of the brain, at the rear of the skull. It serves to connect the other parts of the brain with the spinal cord. It is made up of both gray and white matter, but here the white matter is on the outside. Its tissue structure is like that of the spinal cord, of which it is a continuation. Although the medulla is only about an inch in length, it is the most important nerve center in the body for the control of the internal functions of the body. Breathing, circulation, secreting, swallowing, movements of the walls of the alimentary canal, and some other internal functions would not be possible without this medulla. Considering how forgetful some of us are, we should be grateful for the presence of a physical monitor, or watcher, like the medulla, which attends to so many needed activities of the body without any assistance from our conscious minds.

329. The spinal cord. The spinal cord is the long white cord in the back of the body, passing through the center of the vertebrae, by which it is protected. This cord is about a half-inch in diameter and it extends the whole length of the back. As in the medulla, the white matter is outside and the gray matter is inside.

330. The nerves. From the brain extend twelve important cranial nerves to each side of the head. Each nerve has many branches. From the spinal cord, thirty-one spinal nerves branch out on each side from between the vertebrae, and extend to all parts of the body except the head. A nerve is white, and the small nerves are rather soft, as you may remember from inspection of the nerves in the legs of a frog, when you were studying muscles.

A nerve in its structure resembles an electric cord made up of fine copper wires and covered with rubber insulation material. [See Fig. 15–7.] The nerve cable is covered with a

FIG. 15–7. A cable consists of many strands of wires insulated by rubber or other material.



fatty material. Inside, there are an enormous number of individual nerve fibers. Each fiber is usually insulated from its neighbor, and each fiber usually extends either to the spinal cord or to the brain. [See Fig. 15–8.]

***331. What is the microscopic structure of the nervous system?** Nerves, like other tissues of the body, are com-

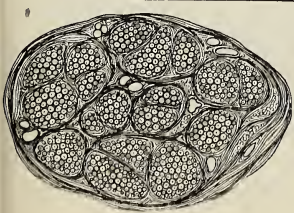


FIG. 15–8. The cross section of a nerve cable shows thousands of nerve fibers, which resemble wires in a cable. A single fiber is too small in diameter to be visible. When these fibers are in a nerve cable, the structure is visible.

posed of cells. Each nerve cell is called a *neuron.* These neurons are peculiar in shape and structure. There are several different kinds of neurons in the human body; their structure differs somewhat with function and location. But each neuron has a *nerve body* which contains the nucleus. [See Fig. 15–9.] Extending from this nerve body are slender,

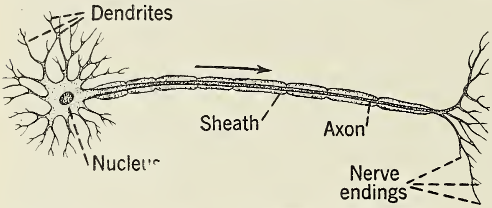


FIG. 15–9. When magnified enough to be seen, one kind of nerve cell looks like this.

branched parts called *dendrites.* (*Dendrite* is the Greek word for tree.) Also from the cell body extends a longer, threadlike part, called the *axon,* from which extend nerve endings. Axons may be short, as in the cortex [see Fig. 15–10], or they may be as long as three or four feet, as in the arms and legs. Axons are sometimes referred to as nerve fibers. Impulses coming to a cell body come in by way of a dendrite; impulses leaving the cell body go by way of the axon, on through the nerve endings. From these nerve endings, impulses are transmitted to the dendrites of the next neuron or

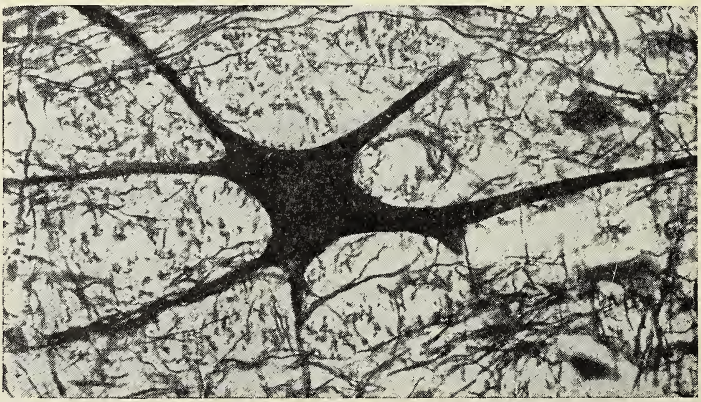


FIG. 15–10. This is a photograph of part of a nerve cell from the brain. The cell has been stained black. (*Julius Weber*)

to the adjoining tissue. The nerve endings of one neuron do not quite touch the dendrites of the next neuron; the microscopic space in between is called a synapse (sĭ·naps′).

There are said to be about 12,000,000,000 neurons in the human brain. One authority says that all the nerve fibers of the nervous system of one individual, if placed end to end, would make a *single nerve fiber reaching at least 50 times around the earth!* The human nervous system is more complex than any device that man has ever made. It is believed that each person is born with the full number of neurons that he will ever possess. New neurons are not believed to develop following birth, although damaged neurons may sometimes be repaired if injured by accident or disease. When a neuron is pinched, pressed, touched, injured, or stimulated by another neuron, a sort of energy, something like electricity, is generated. This current or wave of nerve energy is called an impulse. It travels along the nerve at the rate of about four hundred feet a second, which is much slower than electricity moving along a wire.

*332. **What is reflex action?** Neurons that carry an impulse inward toward the spinal cord or the brain are commonly called *sensory nerves.* Their impulses come from all parts of the body, and are translated by the mind as sensations such as pain, touch, pressure, heat, cold, sound, taste, vision, and odor. Neurons that carry an impulse outward from the brain or spinal cord are called *motor nerves.* Their impulses act as orders producing motion or activity in a muscle, gland, or other organ. Both motor and sensory nerves may be found in the same nerve cable; the insulation we spoke of on page 357 makes this possible. And in both kinds of neurons, the impulse enters the cell body by way of the dendrites and leaves by way of the axon and nerve endings.

The simplest kind of reactions takes place in the lower animals. Touch a worm and it turns. Touch a jellyfish, and sting cells dart out. These are not planned actions; they are reflex actions. Human beings are saved from dangers many

times a day by reflex actions. A branch of a tree sweeps suddenly down near your face. Without thinking or considering what you are doing, you dodge, shut your eyes, and perhaps throw out your arm to ward off the danger. Some dust gets in your nose and you sneeze or cough. You slip but recover your balance. You touch something hot, and before you really are aware of the danger you have jerked your hand away. These are examples of *reflex action.*

Let us take the last example of reflex action and see just what happens in such a case. When the finger touched the hot surface, a nerve impulse was set up immediately in a sensory nerve at the injured place. This impulse was carried in a flash to the spinal cord. Quicker than you can tell of it, the spinal cord automatically sent out along a motor nerve another impulse to the muscle of the arm.

When this impulse reached the muscle, it stimulated the muscle to contract suddenly and jerk the finger away from the danger. The whole action took place so quickly that it seemed immediate. Actually it took a small fraction of a second. Most drivers of automobiles are not aware of this time lapse between their awareness of danger and their pressure downward on the brake pedals. It is quite possible that the person who pulls his arm away from the heat does so without consciously realizing that there is any danger at

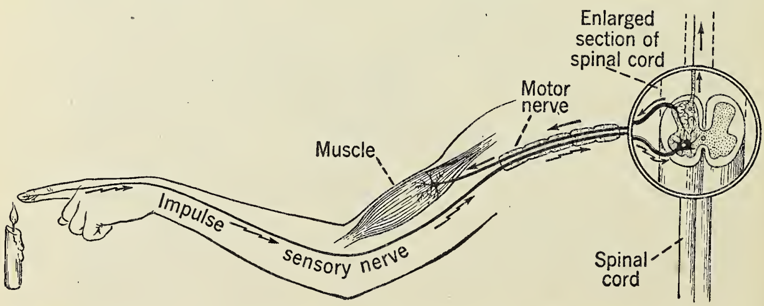


FIG. 15–11. Study this diagram until you can explain the path of nerve impulses in a reflex action.

all. But in the meantime, the original impulse, or another one, has gone on to the brain, and the person now is conscious of what has happened. Now he may use his cerebrum and voluntarily decide to do something else about the incident, such as look at the finger, treat it, or warn others. Also, when the sensory impulse reached the brain, it was translated by the mind into pain as well as a knowledge of the accident. [See Fig. 15–11.]

Reflex actions may be of great assistance to us. They may also affect the beating of the heart and the circulation of the blood with resulting flushing or pallor, cause indigestion, and stop, or *inhibit*, other functions of the body. Worry or other mental disturbances may actually upset the functioning of the organs to the extent of producing illness.

***333. How are reflex actions related to habits?** By repetition, an act may become so reflex that we do not have to think about it in order to perform the action. At first, when the child is learning to write, it is difficult for him to form the words. Each letter is a special problem for the untrained muscles. Gradually, more and more of the act of writing can be turned over to the reflex part of the nervous system, until the time comes when it is not necessary to think about how the letters are going to look. But unless we trained our writing muscles well in the first place, our writing may always be imperfect, even though for ourselves it is reflex. When an adult writes, the mind should direct the ideas and the reflex center control the muscles that move the pen to form letters and words. A skillful pianist may practice a certain selection for a long time. The same muscular movements are repeated again and again. At last the person may sit down at the piano and play the selection without thinking about the notes at all, giving his entire attention to the interpretation of the music.

We often hear it said that practice makes perfect. Actually, *practice makes reflex*. It may or may not be perfect, depending upon the kind of training we have been willing to

undertake in learning. Voluntary acts many times repeated not only become habitual, they become reflex. A large part of the work in our schools consists in training the reflexes so they will function properly. In music, in shopwork, in art, in typewriting, in gymnastics, and in the various games of skill, it is especially important to train the reflexes so that useful and accurate habits of thought and action may be developed. [See Fig. 15–12.]

FIG. 15–12. These girls are learning the touch system, which necessitates memorizing the position of each key. (*Courtesy Katharine Gibbs Schools*)

Because habits so largely become reflex, it is important to make the useful ones automatic as early in life as possible. Bad habits can be broken only by thorough and determined exercise of the will. It is much easier to formulate good habits in the first place.

334. **The central nervous system.** When a person speaks of his nervous system, he usually is thinking of the brain and the spinal cord, that is, of the *central nervous system.* (One seldom thinks of the nerves throughout the body.) [See Fig. 15–13.] Of this system, the brain is the most important part. It is also the largest and heaviest part, weighing from two to three pounds. It is proportionate to the size of the body of which it is a part. The size or weight of the brain, however, has nothing to do with the intelligence of the person. Some

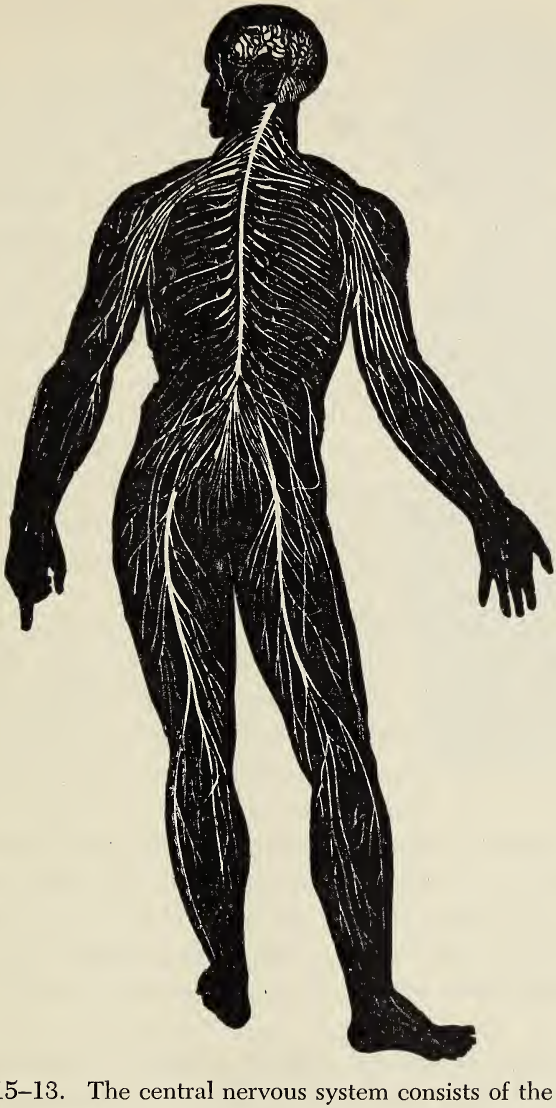


FIG. 15–13. The central nervous system consists of the spinal cord and most of the brain. Branching nerves reach out from these central parts to every other part of the body except the external hair, ends of the nails, enamel of the teeth, and thickened outer skin. By means of impulses carried to and from the central parts along the neurons, messages are distributed throughout the body.

human brains are smaller than the average and some are larger, without relation to intelligence.

The central nervous system is the apparatus by means of which we receive sensations, determine upon action, cause muscles to contract so that the desired act is performed, express emotions, build up air castles and other imaginings, reason, communicate with others, and recall past experiences by the power of memory. Because all of our special senses, except that of touch, are located solely in the head, some persons think that the only existing self is the brain located in the head. Yet fundamentally the brain, in and of itself, is no more intelligent than the feet. One should think about the question of what made this marvelous instrument out of unintelligent and unorganized proteins, water, and mineral matter. Who made the blueprint or design followed by nature in building the intricate human brain and the rest of the nervous system of every individual?

*335. **The autonomic nervous system.** Most people know little about the *autonomic* nervous system. In fact, someone has called this system the secret service department of the body. Inside the body and along the spinal column are several nerve cords, each with ganglia. Branches from these cords unite in a number of places, forming at each a plexus. The largest plexus, called the *solar plexus,* is just over the pit of the stomach. A blow here can produce dangerous results because of the large amount of nerve tissue that might be injured. These nerves and their cords, ganglia, and plexuses constitute the autonomic nervous system. [See Fig. 15–14.]

This system is connected with the central nervous system, but is controlled by it only indirectly. It is influenced by it especially through emotions such as fear, worry, and anxiety. It has to do with gland secretion, beating of the heart, rate of movement of the walls of the stomach and the intestines, respiration, and other internal activities which determine how we feel.

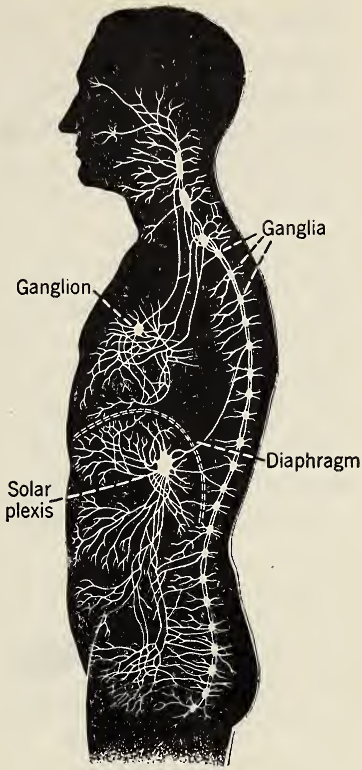


FIG. 15–14. The autonomic nervous system helps to regulate many internal functions, such as the secretion of the glands, the beating of the heart, the activities of the alimentary tract, and the performance of respiration. This system is composed of two parts: the sympathetic and the parasympathetic. The sympathetic consists of a pair of long cords with many ganglia, on either side of the spine. There are also several ganglia and larger plexuses in the trunk. The parasympathetic does not have ganglia along the spinal cord. It has a group of connections in the chest and another in the intestinal region. The sympathetic and parasympathetic work together, but their effects are just the opposite in each function – that is, their action is reciprocal. The autonomic nervous system is controlled indirectly by the central nervous system.

336. To what dangers is the nervous system exposed? There seems to be a widespread opinion that if a person works long and hard there is danger of a breakdown. Such a collapse formerly was called nervous prostration. Now it will probably be termed a *neurosis*. But when such a condition does occur, it is not caused simply by hard work. Mental and physical activity is normal, and it is amazing how much overwork the nervous system can endure. However, since every muscle and gland, and every bone and organ of the body can only perform its duties if its nerves are healthy, it is quite possible for tired and overworked nerves to start organic trouble in the functioning of different parts of the body. What causes an overworked or diseased con-

dition of the nerves? The answer usually is fear or worry over unsolved problems, the results of infection from diseases such as infantile paralysis, or poisoning by lead, alcohol, nicotine, or other drugs.

Conditions of the mind are important not only for a happy existence but also for a healthy life. An experiment performed by Professor Walter Cannon is an important contribution to our knowledge of biology. After giving his cat a good meal of her regular food mixed with bismuth subnitrate, he put her in front of his X-ray apparatus. Bismuth subnitrate does not allow the X rays to pass through it, so that the places in the alimentary canal of the cat where this chemical was, appeared black. [See Fig. 15–15.] The stomach seemed like a black pouch and the regular movements of the muscles of the stomach wall could easily be seen. Pro-

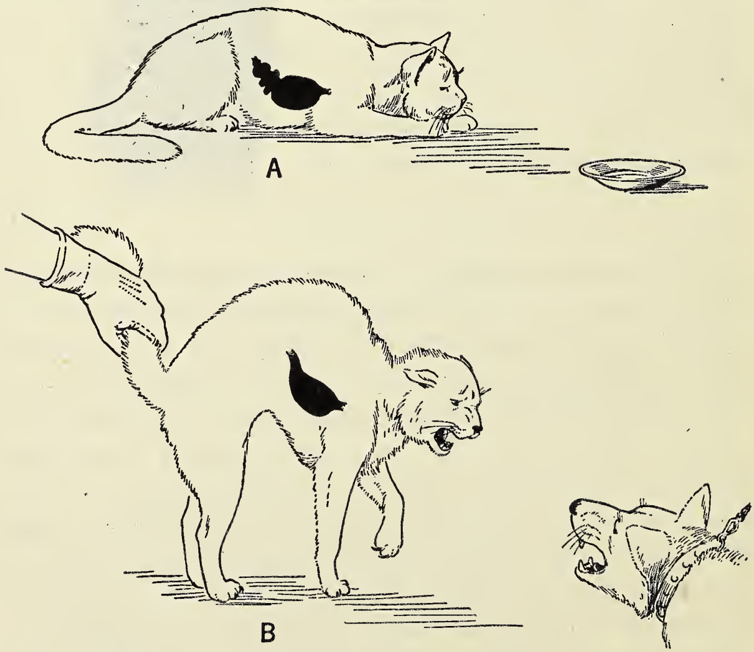


Fig. 15–15. A. The cat shows normal digestive movements in its stomach. B. Digestive movements stop from pain and fear.

fessor Cannon let a barking dog rush into the room, and he also pulled the hair of the cat. The X-ray machine showed that all digestive actions of the stomach muscles had ceased, and they were not resumed for a long time. The fear of the dog and sensations of pain from hair-pulling had definitely affected digestion. Bad mental conditions similarly affect digestion in human beings.

Many persons permit little annoyances to develop into big worries. This is especially true of adolescents, for they have so many adjustments to make, and they do not like to discuss their problems with other persons. Sometimes these secret worries grow so large as to affect the person's mind. This should not happen, for problems can be discussed with parents, teachers, doctors, or other adult friends. A person will feel much better to "get it off his chest," and his mind will be much healthier.

One can let a feeling of inferiority, injustice, or some other emotion become a constant annoyance. If this happens to a young person it may become fixed in his mind. This of course makes the person unhappy. Often the problem fails to be solved because the person never says anything about it to anyone else. The resulting *fixation* of ideas thus becomes a mental habit of life. This may become very serious, leading even to an unbalanced mind. We do not yet know enough about the brain and the mind to say whether diseased brain cells cause such a situation, or abnormal mental ideas cause brain trouble. There are far too many persons now in institutions for the mentally deranged. The present statistics point to the probability that about four per cent of our junior population will in their later life have to enter an institution for the mentally deranged unless something is done to help them.

337. How can the nervous system be safeguarded? Although work is normal, it is not normal to overwork. Temperance means not going to extremes, either physical or mental. The temperate person does not put his nervous system

under excessive strains. Such a person is more likely to live a long life than an intemperate person.

It is also important that all persons recognize that there is such a thing as mental fatigue due to tired nerves, just as there is physical fatigue. A tired brain and nervous system have been shown, experimentally, to make poor decisions. How, then, can one avoid having a fatigued nervous system? The answer must be worked out by each individual in his or her own environment, and working with his or her own heredity. The general rules of health, however, will apply to everyone. Eat balanced meals, scientifically chosen for nutrients and for vitamins; exercise out-of-doors every day even if you do nothing more than take a short, brisk walk; learn to breathe deeply; sleep from seven to nine or more hours according to age and need; and eliminate regularly and daily. If these simple rules are followed with prompt attention to any special needs of your own body, you have done what you should from the physical point of view. In addition, if you have understood the importance of a healthy mind, your nervous system ought to be ready always for the daily demands, and it should have a reserve for special occasions and emergencies.

In connection with diet, there is a strange superstition that if one eats fish one will surely have a good brain and good nerves. Of course there is no truth in such a statement. Nerves are built mostly out of protein and mineral matter. A commonsense diet will furnish excellent building material not only for nerves but for the rest of the body tissues. In some few cases, a special diet directed by a doctor may prove of benefit to the nervous system.

Rest does not necessarily mean only the sleeping period at night. It is any kind of true relaxation or change of activity. It also means freedom from worry and strain. Plenty of sleep is very important, because the growth and repair of the body take place only during such extended rest periods. In fact, you will find, by careful measurements, that

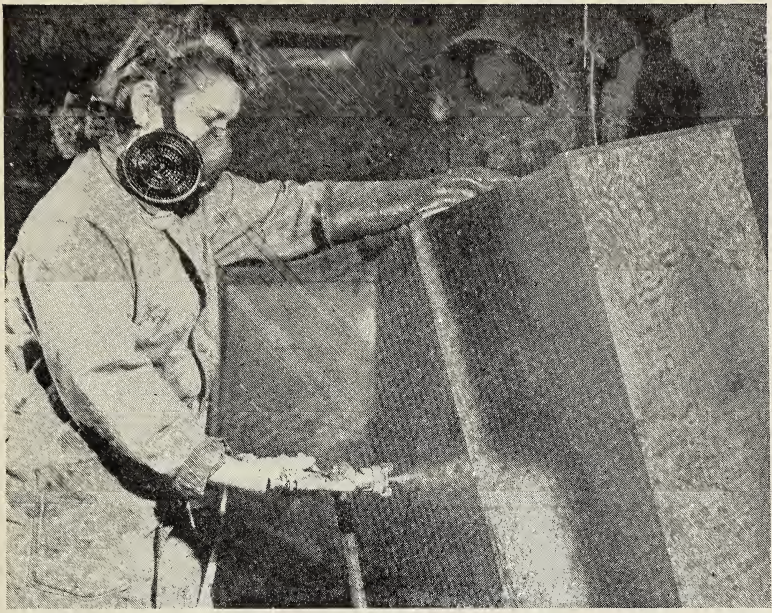


FIG. 15–16. Sometimes a hobby may develop into an occupation. What interests or training may have fitted this girl for her work, which includes the use of a paint spray gun? (*Courtesy NYA Photography Workshop*)

you are taller in the morning than at night, perhaps by as much as an inch. This shows that the muscles, ligaments, and tissues also relax when you are resting.

Every boy and girl should have hobbies. Stamp collecting, photography, plants, birds, other animals, woodcraft, airplane-making, radio, and many other activities are examples of good hobbies. [See Fig. 15–16.] They rest the nervous system from more strenuous duties, and they train the mind so that the person has resources for leisure time. Later in life, such hobbies may be the means of keeping a person normal and happy.

Man is the one organism that is not a victim of environmental circumstances. Plants obviously cannot alter their surroundings; few animals can move far from unfavorable

places and conditions. Man through his intelligence conquers undesirable environment and adapts it to his uses. The development of man is now more mental than physical. Ideas count more than mere physical strength. Happy is the man who succeeds in living a balanced life, expressing constructive and creative mental energy through a sound and well-cared-for physical machine, the human body.

Questions

1. What is the fundamental importance of the nervous system to an individual?
2. In what particulars is the human nervous system better than that of lower animals?
3. What is a ganglion?
4. Can you distinguish between the central nervous system and the sympathetic nervous system?
5. Can you distinguish between cranial nerves and spinal nerves?
6. How is the brain protected?
7. What are the parts of the brain?
8. Why is the cortex important?
9. How can a knowledge of the areas of the brain that govern different body regions be valuable to man?
10. What are the special functions of the cerebrum?
11. What is the cerebellum and what are its functions?
12. What is the medulla and what are its special functions?
13. What is reflex action and how does the spinal cord function in a reflex act?
14. Can you describe a neuron?
15. How many neurons are there said to be in the brain?
16. In what direction does the impulse travel in a neuron?
17. Does the sensory nerve impulse differ from a motor nerve impulse in direction in the individual cell? In relation to the spinal cord or brain?
18. Can you distinguish between a sensory nerve and a motor nerve? What is the function of each?

19. What steps are necessary for a voluntary act to become a reflex and thus form a habit?

20. Do you think that your brain is yourself?

21. To what dangers is the nervous system especially exposed?

22. What care can be given to safeguard the nervous system?

23. Is there any truth in the statement that a large amount of fish in the diet will produce a good nervous system?

24. Why do ideas count more than mere brawn today?

Some things for you to do

1. The next time a hen's head is available, try to take off the skull cap and look at the brain. The skull bones in a bird are rather soft, and it should not be difficult to remove the upper bones by carefully cutting through them with scissors or a knife.

2. Examine under the microscope prepared microscopic slides of nerve cells.

3. In an encyclopedia or other reference book, read enough about Pavlov's interesting experiments on reflexes to write a short report on what you have read.

THINK ABOUT THESE!

1. How do your special senses compare with those of some animal with which you are familiar?
2. Have you a blind spot in your eyes?
3. Why is your inner ear sometimes compared to a harp?

WORDS FOR THIS CHAPTER

Aqueous (ā′kwḗ·*ŭ*s). Watery.
Vitreous (vĭt′rḗ·*ŭ*s). Glassy.
Retina (rĕt′ĭ·n*ȧ*). The membrane of the eye, which receives the image in vision. The retina is connected with the brain by the optic nerve.
Convex (kŏn′vĕks). Rounded; shaped like the outside of a sphere.
Diverging (dĭ·vûr′jĭng). Spreading apart; separating.
Concave (kŏn′kāv). Hollowed; shaped like the inside of a sphere.

CHAPTER 16 ________________ UNIT 7

How Do Our Special Senses Help Us?

338. What are the special senses? The special senses of seeing, hearing, tasting, smelling, and touching are important factors enabling man and the higher animals to live as successfully as they do. The loss, even temporarily, of the sense of smell, for example, deprives us of much of our enjoyment of the so-called flavor of food. For a wild animal like the fox, the loss of smell might mean death, because he would be less able to find food or detect the nearness of enemies. If we are deprived of sight, the handicap is much greater.

Sometimes when you have a cold, you lose much of your sense of smell, and you think that your sense of taste is affected. In extremely dark places, you find that your sight is of little use. When you are wearing gloves, you gain protection, but your sense of touch is interfered with. It is only through one of these temporary losses or handicaps that

FIG. 16–1. This is the view that one can see on a clear day, looking north from the top of the Empire State Building in New York City. (*Courtesy Empire State Building Corp.*)

most of us can understand the importance of the faculties that we usually take for granted.

Perhaps the most striking case of victory over complete loss of important senses is the story of Helen Keller, who is deaf, mute, and blind. Through the assistance of her teacher, Miss Sullivan, she learned to express herself through speech — which she never heard — and through writing — which she never saw. She even learned to understand this world and its peoples. Some time you should read her description of a trip she made to Niagara Falls, and of the sights to be seen from the top of a skyscraper in New York City. [See Fig. 16–1.] Take especially good care of your eyes and ears, for they cannot be replaced. And be grateful for all your senses.

339. **What do we mean by the visual apparatus?** Vision is one of the most remarkable functions of the human body and mind, shared of course by the higher animals. The structures involved are so complex and their action so puzzling that no one can explain all that happens when we see.

But we can understand much of the *visual apparatus* and how it works. In the first place we must get acquainted with the parts of the eye.

340. What are the parts of the eye? By looking at your own eye in a mirror, you can see the external structures. The internal structures are shown in Figure 16–2.

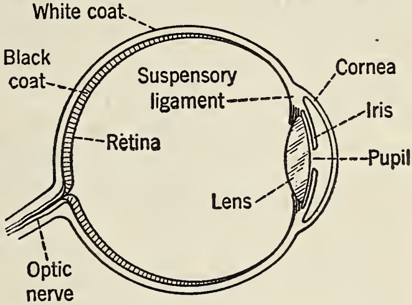


FIG. 16–2. This diagram shows a cross section of the human eye. The window in front is the cornea. Does the shape of the eye look like a part of any instrument with which you are familiar?

Vision depends upon light, and the protecting front of the eyeball is a clear window, called the *cornea* (kôr′nē·ȧ). Around it is the white of the eye, composed of tough, strong membranes, in which are many blood vessels. If you look directly into your own eye, you will see a dark spot in the middle. This is the pupil. By means of the pupil, light is admitted into the interior of the eye. The pupil is surrounded by the colored part of the eye, the *iris*. This structure was named after the goddess of the rainbow, whose name was Iris. The color of the iris determines eye color. It is interesting to note that the color of the eyes of newly born babies is always blue. Later, this color may change to another color, or the eyes may remain blue. The pupil of the eye automatically becomes larger or smaller according to the amount of light present.

Light from any object, entering the eye through the pupil, passes first through the *lens*. In health this is a clear, colorless structure. In front of the lens is a liquid called the *aqueous humor*. After the light passes through the lens, it goes through another clear liquid called the *vitreous humor*, which

fills the cavity behind the lens. This cavity is as dark as a cell in a dungeon, except for the rays of light coming in through the lens. On the rear wall of this rounded cavity is a curtain of dark material called the *retina.*

Actually the retina is a complex structure of ten layers. The rays of light, in passing through the rounded lens, are bent just as they are when you use a *convex* lens. [See Fig. 16–3.] If the lens of the eye is true in shape and adjusts

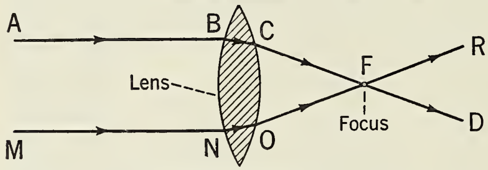


FIG. 16–3. Rays of light are bent when they pass through a convex lens.

itself, by means of muscles, to the distance the object is from the eye, a sharp picture of the object will be thrown upon the retina. This picture, however, is *upside down,* and *reversed,* right for left.

The retina is supplied with many nerves, and with peculiar nerve cells called *rods* and *cones.* [See Fig. 16–4.] The

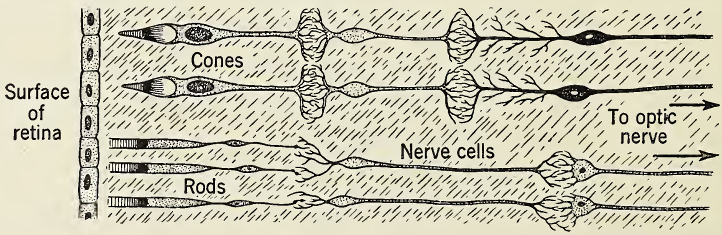


FIG. 16–4. If you can see well at night, or in dim light, you probably have an unusually good supply of rods in each retina.

rods seem to make the retina more sensitive in the dark. Persons who have poor vision at night, or in dim light, probably have fewer rods than do persons with normal vision. Foods, like carrots, containing vitamin A, help to improve the sight at night. The cones are more important than the rods for ordinary vision. When light strikes these cones or rods,

they are stimulated. They begin to send impulses to the visual center of the cerebrum by means of the optic nerves. This visual center is at the back of the head, the part of the cerebrum directly over the cerebellum. When the impulses set up in the optic nerves reach this part of the brain, the mind interprets the stimulus as vision, or awareness of things by sight. Sight can be defined as the mental interpretation of the impulses set up in the optic nerve and in the visual tract of the brain, by light waves striking rods and cones in the retina of the eye. The inverted image on the retina is seen erect and normal. The separate images in each eye are seen as one picture. And although the size of the retina image is very small, we see the object in correct dimensions. Just how vision is thus producd from nerve impulses is not known. [See Fig. 16–5.]

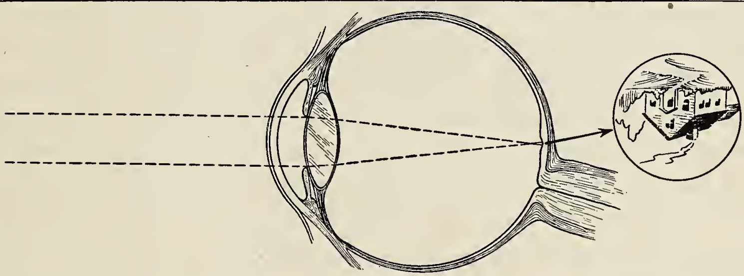


Fig. 16–5. The image on the retina is inverted, is changed left for right, and is smaller than the period at the end of this sentence.

Although light rays entering the eye are the source of normal vision, sudden pressure on the eyeball, as by a blow, can produce a sensation of light. This explains the experience of "seeing stars" from a blow on the head near the eyes.

341. What is the range of vision of your eye? The eye has a large range of vision. You can easily prove this. Close your left eye, then with the other look steadily at some object directly in front of you. Now lift your right hand and move it slowly around to your right. Notice how long you

can see it, even though it is somewhat indistinct. If you move your hand up and down while moving it away, it will be easier to observe. Your right eye should have about a 90° scope of vision to the right. The left eye should have about the same scope to the left. The right eye cannot see equally far to its left, nor the left eye to its right, because the nose partly obstructs vision.

Although objects can be recognized off to the extreme right or left, they are only dimly seen. You cannot be sure of the number of separate parts of an object, for instance, unless it is almost directly in your line of sight; that is, unless you are looking directly at it. Nor can you accurately describe the shape or the details of such an object, if it is outside the line of direct vision. Test yourself until you are sure about this. The reason is simple. The retina is not equally sensitive in all places. In fact, the most sensitive part of the retina, by means of which most of our vision occurs, is a tiny spot less than one-half the size of a pinhead. In this almost microscopic region there are no cones, but there is instead an enormous number of rods. The picture of anything we look at is so small, after being formed by the lens and cast on the retina, that the image fits *inside* such a minute area. We move our eyes continually, without realizing it, so that we may look directly at an object; its impression thus falls on this sensitive spot. Surrounding this sensitive spot is a larger area by means of which color can be recognized. Color of objects cannot be noted easily unless the object or scene is in the line of direct vision, or nearly so.

*342. **What is the blind spot?** Curiously enough, there is a blind spot in every healthy retina. This is the place where the optic nerve enters the eye. There are no rods or cones here, and this area is not sensitive to light. You can find your blind spot by following the directions given under Figure 16–6.

343. **What is color blindness?** Some persons are unable to recognize certain colors. This condition is called *color*

FIG. 16–6. To find your blind spot, close your left eye, hold this diagram about 6 inches from your right eye, and look steadily at the circle. Move the book closer and then farther away. In one place you will not be able to see the cross. That will be when its image falls upon the entrance of the optic nerve, where there are no rods or cones.

blindness. Red-green color blindness is the most common form. Persons who have it see both red and green as the same dull gray-brown color. Blue-yellow color blindness is the next most common form. Blue and yellow seem to be the same dull color to persons with this form of color blindness. Some persons are totally color-blind and cannot distinguish any color from another. Everything they see is white, gray, or black, like a motion picture which has no color.

For many years persons with red-green color blindness had difficulty in driving through city streets in which there were red and green traffic lights. [See Fig. 16–7.] In some places traffic lights are now blue-green and yellow-red, in order to permit persons with red-green or blue-yellow color blindness to drive safely in traffic. But these lights do not make it really safe even for persons who are only partially color-blind. Some cities now have all the green lights above the red lights. If all traffic lights followed this scheme, any color-blind person might drive safely in traffic. However, at present, it seems doubtful whether color-blind individuals should be licensed to drive automobiles. About 4 per cent of the males and about 0.4 per cent of the females of our population are color-blind.

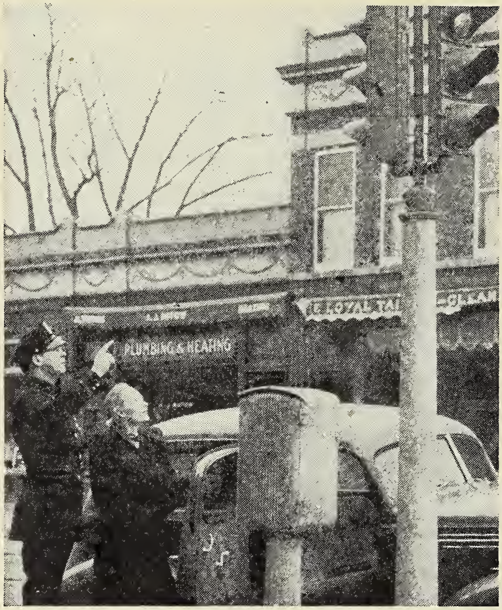


FIG. 16–7. The familiar green and red signals of traffic lights are signals which can be recognized by all persons except those who are color-blind. About four out of every hundred men are color-blind. It is doubtful whether a person who is color-blind should be licensed to drive an automobile. (*Courtesy National Safety Council*)

344. How does the lens of the eye work? Light normally travels in a straight line. It is possible, however, to change the direction of the rays of light, by having them pass through some material other than air, such as water or glass.

Thus if light rays from a burning candle are passed through a *convex* lens, the rays from the candle are bent and brought to a focus on the other side. The distance from the lens to this *focal* point is called the *focal length* of the lens. If the lens is greatly curved, the focal distance is very short. Light rays coming from distant points are parallel. They can be brought to a focus by a convex lens in a shorter distance than the focal distance of *diverging* rays from a near-by object. [See Figs. 16–8 and 16–9.]

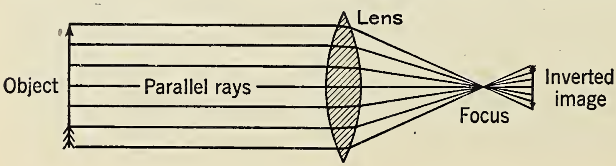


FIG. 16–8. Parallel rays focus nearer the lens.

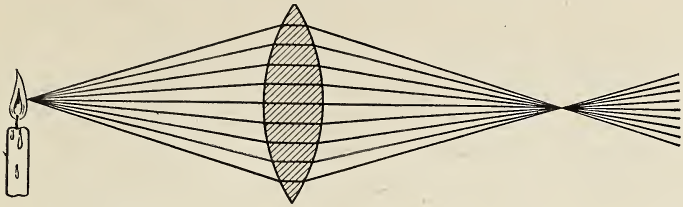


FIG. 16–9. Diverging rays focus farther from the lens.

Some of you know that in a camera of the bellows type, the lens has to be moved farther away from the film, as one approaches closer to the object or person to be photographed. If, instead, we could keep changing the curvature of the lens in the camera, making it more and more rounded as we get nearer the subject to be photographed, we would have the image constantly focused on the film or the ground glass without moving the lens forward.

The transparent, or *crystalline* (krĭs′tăl·ĭn), lens of the eyeball is a beautiful lens. It looks and acts like the lens of a camera, but it is much more than that. Its shape can be changed quickly. By means of muscles, this lens can become more rounded in order to make the rays of light coming from a near-by object focus on the retina. Neither the lens nor the retina in the human eye can be moved apart to increase the distance between them. The curvature of the lens is altered for clearer focus. When the lens becomes more rounded, we can see near-by objects as clearly as we do distant scenes. This ability of the eye to change its shape is called *accommodation.* If the lens did not have this wonderful property, we would be able to see clearly only at one particular distance from the lens of our eye. To prove to yourself that your eyes can *accommodate,* first look at something as far away as possible. Then, while still looking away, bring a picture or the page of a book into the line of vision. The picture or page will be blurred until you look directly at it. The details will suddenly become clear and distinct. The lens became more rounded, so that the di-

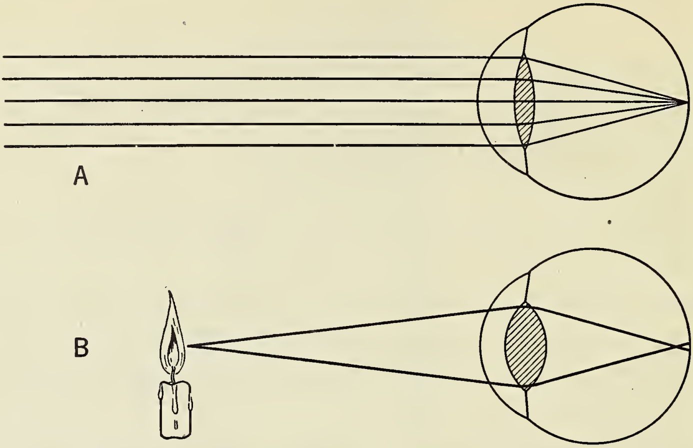


Fig. 16–10. How is accommodation produced by altering the lens?

verging rays of light from the near-by picture or page might be focused sharply on the retina. This all happens automatically. [See Fig. 16–10.]

345. How is poor eyesight caused? Inability to see objects clearly may result from any one cause or from combinations of causes.

a) The lens may be unusually short and rounded. This would cause the person having this weakness to bring a book or object nearer to the eyes than do other people. A person with such lenses is said to be *nearsighted.*

b) On the other hand, the lens may be abnormally flattened. Such a lens may allow long-range vision of distant objects, but never can successfully see near-by objects or ordinary print clearly, unless they are held at more than the usual distance from the eyes. A person with such lenses is said to be *farsighted.*

c) The crystalline lens may not be equally well-rounded over all of its surface. It may have slight elevations or depressions. Such a lens cannot produce a perfect image throughout the entire picture cast on the retina. The part of the image produced by light rays passing through the im-

perfect portion of the lens will be blurred even though the rest is a perfectly clear picture. This fault in human eyesight, due to flaws in the curvature of the lens, is called *astigmatism* (ȧ·stĭg′mȧ·tĭz′m).

d) The crystalline lens may not be elastic enough to produce accommodation. The image cast from distant objects by parallel rays of light focuses correctly and makes a sharp image on the retina. That is, the person sees clearly distant scenes. But often, owing to old age, the lens of the eye does not become more rounded as normal eyes do. Divergent rays of light from near-by objects are not seen clearly on the retina. This means that in such a person, all near-by objects blur, even though the person can see clearly at a distance.

e) The muscles of the two eyes may not be balanced properly, and as a result the two eyes do not look directly at the same object. A person with this affliction is said to be cross-eyed. In severe cases, it may result in double vision. Difficulties with muscle balance are also revealed when one eye or both eyes look outward instead of straight ahead, and when one eye looks above or below the line of vision of the other eye.

Each healthy eye, in any person, sees an image. Prove this to yourself by focusing your eyes on a small object about three feet away. Close one eye, leaving the other open; then close the other eye, leaving the first one open. Do this rapidly several times, and you will see the object appear to shift position. This is not due to an imperfection of vision. It is actually an aid to vision. Prove this by closing one eye and looking about the room. You can judge two dimensions of an object – height and width. You cannot, however, tell accurately how far away an object is. When both eyes are used, you can judge a third dimension – distance from you.

f) The lens, instead of remaining clear, may become cloudy or white. This condition is caused by the deposit of substances in the lens, probably through lack of proper

diet. Such a condition is called a *cataract*. For a time it only partially interferes with sight, but eventually it will block out all vision.

346. What are the remedies for poor eyesight? Perhaps in no other way has science brought help more effectively to human beings than by enabling them to wear properly prescribed glasses, and thus correct many eye defects. The physical and mental relief that can be obtained is amazing. Eyestrain is frequently the cause of headaches, indigestion, and various forms of nervousness. Not only are such disorders relieved by proper glasses if due to eye defects, but good vision brings a new satisfaction to the individual. [See Fig. 16–11.]

Properly fitted glasses can correct only the first four of the errors in sight which we have described. The only remedy for cataract seems to be to have the entire lens removed by a surgeon. This operation is fairly common. It leaves the person without any lens in the affected eye, but vision of a sort is restored by using glasses to replace the lens.

FIG. 16–11. Having one's eyes examined by a specialist is as important as regular visits to a dentist. (*Courtesy Better Vision Institute*)

Nearsightedness may be corrected by the wearing of *concave* glasses, the lenses of which bring the rays of light to a focus a little farther back in the eye, so that the image falls sharp and clear on the retina. [See Fig. 16–12, A and B.]

Farsightedness may be corrected by the use of convex glasses, which bring the rays of light to a focus farther forward in the eye, so that the image is now directly on the retina in sharp focus. [See Fig. 16–12, C and D.]

Astigmatism, the most common eye defect, can easily be corrected by the use of eyeglasses ground to correct the unevenness of the crystalline lens.

The aging lens that cannot accommodate is helped by bifocal, or double, lenses. The larger area of these lenses is

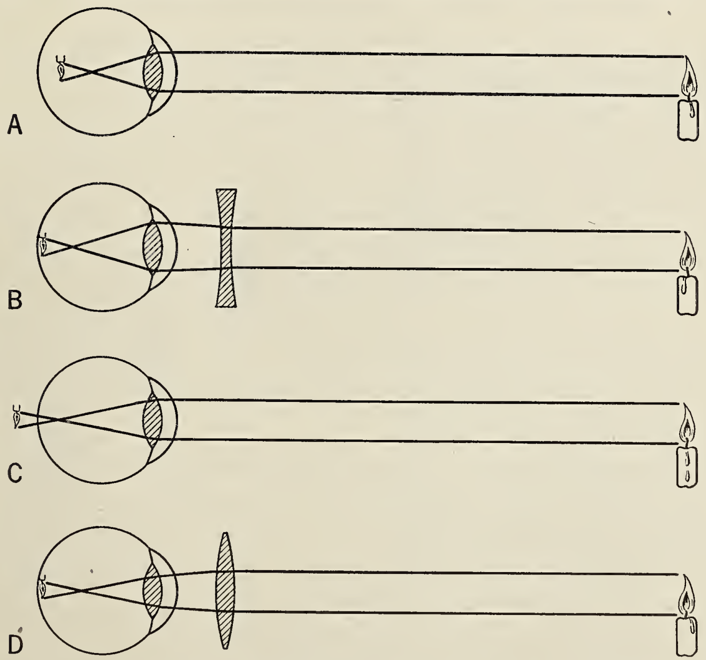


FIG. 16–12. A. Nearsightedness; lens too thick. Corrected in B by using a concave lens. C. Farsightedness; lens too thin. Corrected in D by using a convex lens.

fitted to the individual for distant vision. In the lower part of each eyeglass is a smaller section for reading or viewing near-by objects. Of course eyeglass lenses have no accommodation at all, so that printed material and near-by objects will be in focus *only* at a certain fixed distance from the eyes, usually between twelve and fifteen inches. Provided with such glasses, the aging eyes are almost as good as ever.

347. **What are optical illusions?** There is an old statement to the effect that "seeing is believing." This is true; sleight-of-hand artists and other mystifiers get you to observe – and thus believe – *only* what they want you to see. The unaided eye does not always tell the truth. A simple illustration of an *optical illusion* is furnished by two parallel lines, such as the iron tracks of a railway. The rails appear to be closer and closer to each other the farther away you look. Yet a mile or two distant from you, where they appear to join, you know that they are exactly the same distance apart as they are where you are standing. [See Fig. 16–13.]

Motion pictures give us the illusion of action. This is due to the *after-image,* which is the memory, or mental picture, which lasts for a moment after we see something. This after-image remains after each *still* picture, for motion pictures are really a series of still pictures changed very rapidly. Thus we unconsciously bridge over changes on the screen. The action seems to be continuous. We may be deceived even more by the spoken word or sounds normally associated with the particular action.

Errors in judgment as to size, distance, and the relation of form and lines, are often due to inaccuracies in our vision. Seeing may be believing, but we should remember that all superstitions are based on beliefs. Be slow to accept as truth what may be only a belief of an individual or a group. The magician baffles us partly because he is so deft and clever, but also because he makes things appear to be what they are not. We are fooled and believe what he wants us to believe. Many advertisers, politicians, "high-pressure"

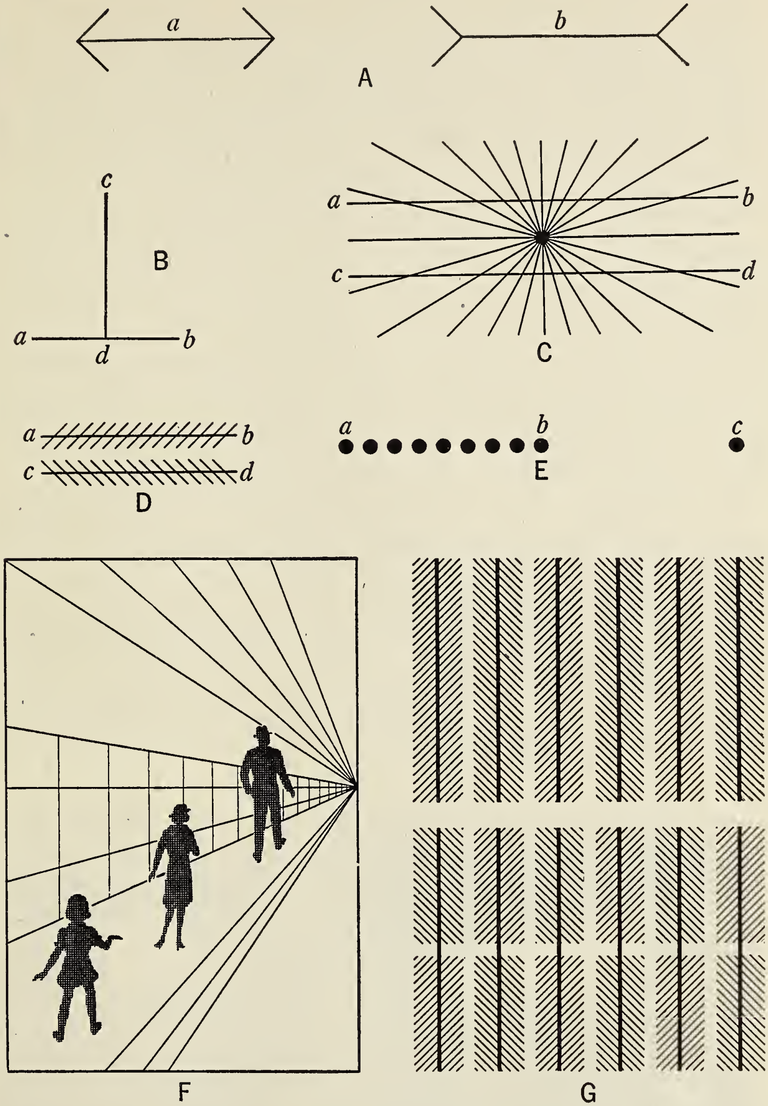


FIG. 16–13. Can you believe your eyes? A. Compare the length of *a* with *b*. B. Compare the length of *a-b* with *c-d*. C. Are *a-b* and *c-d* parallel? D. Are *a-b* and *c-d* straight lines and parallel? E. Compare lengths *a-b* and *b-c*. F. Compare heights of the individuals. G. Are the heavy lines straight and parallel?

salesmen, and the like, use similar tactics. Mr. Barnum after running for years the largest circus in the world said, "The American people like to be humbugged." But Abraham Lincoln also said, "It is true that you may fool all the people some of the time; you can even fool some of the people all the time; but you can't fool all of the people all the time."

348. What care should be taken of the eyes? (*a*) If the vision is impaired so that one does not see equally clearly and distinctly the printed page and also the distant view, that person should consult an eye specialist. An *optometrist* (ŏp·tŏm′ĕ·trĭst) is a person trained in diagnosing defects of vision, and prescribing the proper glasses to remedy these faults. An *oculist* is also an eye specialist; furthermore, he has a medical degree. An *optician* makes or sells glasses.

b) Young persons should early form the habit of studying and reading in a good light. Using the eyes in dim light is very likely to strain the eyes.

c) In reading, one should sit so that the light comes from the side and slightly from the rear. In writing, the light should come from the side opposite the hand you use – from the left, if you are right-handed – thus avoiding shadows on the work. [See Fig. 16–14.]

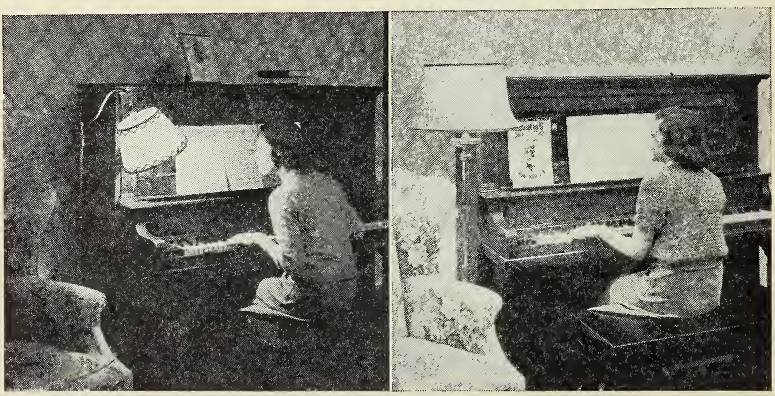


FIG. 16–14. A light which is too strong or too close produces glare. Indirect lighting gives even, soft light. (*Courtesy General Electric*)

d) Reading in too bright a light, with the page in direct sunlight, for example, is equally bad. Likewise, studying in the glare of a light directly facing the eyes, or reflected from too glossy paper, is bad for the eyes. Do not use cheap dark glasses which may damage your eyes. Eyesight is too valuable. If you are forced to work in too bright a light, glasses with Crookes lenses will safely eliminate the glare. For less close work, Polaroid glasses are equally good.

e) Some persons find it advantageous, upon arising in the morning, to rinse their eyes with cool water, thus cleansing them from various secretions.

349. What is the ear? The ears, or outer appendages on each side of the head, are not organs of hearing. However, each of these *auricles* (as they are called) helps to catch sound waves and direct them to the true ear. Most of the ear lies buried out of sight in bony canals. Here there are microscopic structures even more delicate than the rods and cones of the retina. There are three divisions to an ear: the outer ear, the middle ear, and the inner ear. [See Fig. 8–5.]

350. What are the parts of the outer ear? Everyone knows the ear opening on the side of the head. This is a short tube, the *auditory canal,* which leads through a wall of bone inward about an inch and a half to the drum membrane. This eardrum, as it is commonly called, is a flexible partition between the outer ear and the middle ear. By means of a small muscle, the eardrum can be tightened, a necessary condition for hearing shrill sounds.

351. What are the parts of the middle ear? The middle ear is a tiny chamber extending from the eardrum to the inner ear. It resembles a cave, dug out of solid rock, having one round entrance and three windows of some flexible stuff like cellophane. The entrance is the upper end of the canal – the Eustachian tube – which begins in the throat at the back of the inner nostril opening. By means of this tube, air can be admitted to the middle ear. Thus when air pres-

sures change, through natural weather conditions or by man-made circumstances (such as going up in an airplane or going into a pressure chamber), pressures on both sides of the eardrum can be equalized.

The outer window is the eardrum. There are two windows on the inner wall of the middle ear, each closed by a membrane. Stretching across from the eardrum to these inner windows are three tiny bones. The outer bone is called the *hammer*. The middle one is called the *anvil*. The inner one is called the *stirrup*. One end of the stirrup rests against the larger of the two inner windows.

*352. **What are the parts of the inner ear?** The inner ear is so complicated in its structure that a full description is difficult.

The inner ear, or *cochlea*, looks somewhat like a small shell. Yet it is, in reality, a small coiled tube surrounded by solid bone. This tube is lined with living membranes. It is also divided by delicate partitions into three cavities which extend throughout its coiled length. These cavities are filled with a liquid. On the floor of the middle cavity are tiny hair cells. From each projects upward a microscopic hair. These hairs are larger in the large part of the cochlea and are smaller toward the inner end of the cavity. Each hair cell at its base is provided with a branch of the auditory nerve. Above the hair cells, floating in the liquid, is a membranous structure called the *roof membrane*. [See Fig. 16–15.] In the membranous floor underneath the hair cells are about 24,000 tiny fibers of different lengths. This part of the inner ear is somewhat like a harp. We may well wonder how living microscopic structure can be developed with such precision, balance, and proportion. Perhaps the greatest wonder of all is that creative energy uses, for building material, portions of meat, fish, eggs, and beans, wherever that precious nutrient called protein can be obtained. You will marvel the more when you see how this apparatus works, that is, how you hear.

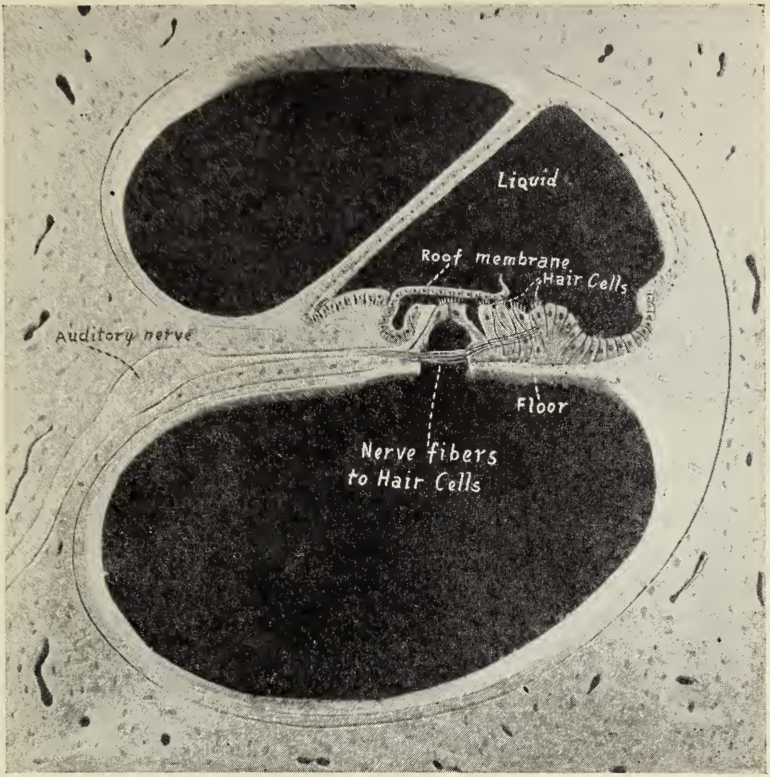


FIG. 16–15. A section through the three chambers of the cochlea shows hair cells and other parts. (*Ward's Natural Science Establishment*)

***353. What happens when we hear a sound?** We are ready to discuss the problem of how vibrations or sound waves reach the brain and are interpreted as sound.

Suppose that someone strikes the key on the piano which produces what is called middle C. This vibrates 256 sound waves a second. It may be difficult to realize that these *sound waves are really silent.* The sensation called sound is not produced until these waves reach a living ear, and subsequently are interpreted as sound. At this stage they are silent waves traveling through the air at the rate of about one-fifth of a mile a second. Some of these waves are caught

by human ears, perhaps your own. Then the waves pass through the auditory canal and set the eardrum vibrating at just the same number of times per second as the original waves coming from the vibrating C string on the piano.

The vibrating eardrum sets the three bones in the middle ear to vibrating and at the same rate. The vibrations of the foot of the stirrup against the window cause waves in the liquid of the inner ear, and at the same rate as the original sound waves. These waves in the liquid agitate the hairs of the hair cells and the delicate roof membrane floating in the liquid in the cochlea. Low notes (fewer waves per second) seem to set the longer fibers in the membranous floor to vibrating. High notes (many more waves per second) set the shorter fibers to vibrating.

Thus different kinds of nerve impulses are set up in the tiny nerve branches of the auditory nerves which connect with hair cells and fibers. These impulses travel along the auditory nerve to the auditory centers of the brain. Your mind then translates such impulses into the sensation called *hearing*, with knowledge on your part of *pitch* (high or low placing of note), of *timbre* (the kind or quality of sound), of *intensity* (loudness or softness of sound).

Only now is sound truly produced. Thus sound is the mental interpretation of nerve impulses which have been set up in the auditory nerve and in the auditory canal, by sound waves coming into the inner ear and affecting the liquids, hairs, and membranes.

354. Of what importance are the semicircular canals? In addition to the cochlea, each inner ear contains three strange rounded cavities or canals. They are called the semicircular canals. Each cavity lies on a different level and at an angle to each of the others. The semicircular canals are filled with liquid. In each canal is a rounded bone like a tiny marble, and also delicate hairlike projections. [See Fig. 16–16.] The semicircular canals are the chief means of maintaining the balance or equilibrium of the body.

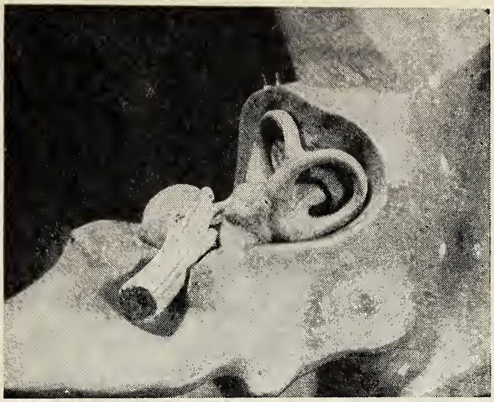


FIG. 16–16. This is a photograph of a model, showing the auditory nerve extending from the loops of the semicircular canals. The three semicircular canals of each ear are of the greatest help to each of us in balancing the body. (*Ward's Natural Science Establishment*)

The theory is that when one changes position, the liquid in the semicircular canals rises or falls accordingly, like water in a dish which is tipped first one way, then another. This motion of the fluid in the canals carries along the bony pellet. As it moves, it touches the hairs. These contacts give rise to nerve impulses. Such impulses when brought to the brain are interpreted as knowledge of changes in position or posture. Then other motor impulses are immediately sent out automatically from the brain to various body muscles to act to maintain balance or to change position as needed.

The semicircular canals are of especial importance to persons such as tight-wire and flying-trapeze performers or mountain climbers, whose lives may depend upon the maintenance of perfect balance. However, it is equally important to us, in our daily lives, since we could not otherwise walk, swim, run, or accomplish any co-ordinated movements resulting in posture balance or locomotion of the body.

355. What care should be taken of the ears? From what we have learned about the ear, we must conclude that it is a very delicate organ. The inner ear is protected from injury by its position in a little cavity in one of the hardest bones of the body. The middle ear, too, is fairly well protected. A natural wax is secreted by glands in the canal of

the outer ear. This wax is sticky and bitter, and it has a tendency to repel insects that might crawl into the ear. Nature seems to have done her part in the protection of the ears. What can you do?

a) You should avoid using any hard substance, such as a pin or a pencil, to remove particles of wax from the outer ears. Such practice may injure the drum permanently. It may crowd wax down against the drum, and prevent the drum from vibrating when the sound waves strike upon it. If an excess amount of wax accumulates, one should see a physician.

b) Some parents box a child's ears as a punishment. Such a sudden forcing of air into the outer canal of the ear may rupture the drum. It was such a blow upon the ears of Thomas A. Edison that ruptured his eardrums and caused his deafness for the remainder of his life. It is said that Edison counted his deafness as one of his blessings, because he did not have to listen to a great deal of foolish talk; but most persons would not agree with him. Even a loud shout directly into the ear may injure the sensitive drum. Soldiers who fire heavy artillery are likely to have their ears injured by the intensity of the sound waves, unless they swallow and then open their mouths so that the Eustachian tubes are opened and the air pressures equalized on both sides of the eardrums.

c) In swimming or in diving, the outer ear should be covered to prevent water from being forced into the outer ear. Diving, in particular, may make the eardrum undergo a great deal of strain.

d) One should use care in blowing the nose. If the nostrils are pinched shut and held while the nose is blown vigorously, mucus may be forced up into the Eustachian tube. The mucus may carry with it some bacteria which cause infection. A person should never pinch the nostrils shut when blowing the nose. Doctors are well aware of the fact that ear and throat infections may come from swimming pools which are not properly disinfected.

e) If ear or throat trouble persists, one should consult a specialist. Some remedies that are advertised in papers and magazines may be positively injurious.

356. What is the surface of the tongue like? If you look at your extended tongue in a mirror, you will notice that the surface in the front is rough, somewhat like plush, on account of minute projections. These projections are called *papillae* (pȧ·pĭl′lē). Toward the rear of the tongue, the papillae are larger. In the case of the cat and dog the papillae are quite rough and aid in lapping up water. In the cow and deer they make the tongue as coarse as a file.

357. How do taste buds work for us? Scattered among the papillae are sensitive cells of taste. A group of these cells form a sort of cup called a taste bud. Each of the sensitive cells terminates in a tiny hair. The taste bud when magnified appears from the surface to be a small opening filled with a number of hairs. Each taste bud is supplied with delicate nerves. [See Fig. 16–17.]

FIG. 16–17. A taste bud is a small opening lined with sensitive cells, each ending in a hair.

There are four primary sensations which are recognized by scientists as pure taste: sweet, sour, bitter, salty, and, according to some, also alkaline. Most of the so-called flavors which we think we are tasting are sensations of odor. If we hold our nose for a time when eating, we can see that this is true. It is further proved by the loss of what we usually think of as taste ability when we have a cold and cannot smell. In addition to the four taste sensations, we also have a burning sensation from pepper, ginger, and other spices.

The front of the tongue is especially sensitive to sweet and salty substances. The sides of the tongue perceive sour tastes. Anything bitter is tasted most at the back of the tongue, and even in the throat. The middle part of the tongue is not used for tasting.

We cannot taste a substance unless it is in a dissolved state. The saliva assists in tasting because it helps to dissolve many substances. When some of the dissolved substance gets into a taste bud, it stimulates the hairs and thus the sensitive cells. This causes a nerve impulse to pass from the cells in a taste bud along the nerve of taste to the taste center of the brain. The mind then interprets these impulses.

358. How does man's ability to detect odors compare with that of some other animals? Everyone knows how valuable to a dog in tracking another animal is his acute sense of smell. Many wild creatures have an extraordinary ability to detect odors. Moths have been known to come to an imprisoned moth from a distance of several miles.

Compared with these animals, man's ability to smell is very weak indeed. However, this fact should not deprive us of the satisfaction we do get from odors. This sense of smell can, however, be developed. Hunters and persons who work with gases often make good use of this sense.

359. What are the organs of smelling? High in the upper part of each of the two nasal cavities is a layer of mucous membrane. Here are located many elongated sensitive cells called *olfactory cells,* with connections to the olfactory nerves, which lead to the olfactory center of the brain, where the odors are interpreted.

360. How do we use our sense of smell? If a substance is to be tasted, some of it in solution must reach the taste buds of the tongue. And, in order to smell a substance, some of its particles must come to the olfactory cells.

Most persons do not know that when one smells a perfume or a flower, extremely small particles of the perfume, or of the essence of the flower, are cast off into the air and

drawn into the nose. They do not see the particles unless the particles are very much concentrated, as smoke is.

When particles do get into the nose, they are usually carried by warm currents up to the roof of the nasal cavities. Here they excite the olfactory cells. An impulse is set up in the nerves leading from these cells and later in the large olfactory nerve. When this impulse reaches the olfactory tract of the brain (the front of the brain), it is identified by the mind as odor.

361. What kinds of nerve impulses come from the skin? There are four possible kinds of stimulations from the skin that covers the body and lines the mouth and throat, because there are four kinds of nerve endings scattered through the skin. (See section 242 on page 265.) The resulting sensations are temperature, pressure, touch, and pain.

Nerve endings that get impulses of pain are the simplest of all and the most numerous. In the cornea of the eye the only nerve endings are those for pain; consequently the eye feels hurt by a strong light or by delicate contact which would be noticeable only as touch elsewhere on the body.

***362. How can you experiment to find the locations of sensitive spots on the skin?** Touch the skin on your arm or on the back of your hand with the point of a metal instrument, quite warm but not hot enough to burn. You may or may not experience a sensation of heat. Try various regions until you are satisfied that there are certain spots only that are really sensitive to heat. Similarly, if you use the same instrument when it is cold, you can locate some of the cold spots in the skin. By simply drawing the point of the instrument, unheated and at room temperature, lightly across the skin, you experience the sensation of touch. (A pencil can also be used.) Only certain spots are sensitive to touch. But these touch spots, like heat and cold spots, are close enough together so that we do not usually touch anything without realizing it. If you press the instrument firmly down on the skin, you feel pressure or weight. If the point

of the instrument is pushed against the skin, or the skin is actually pricked with a clean needle, you experience a sensation different from any of the preceding four, pain. If you try this experiment, the place selected on the skin should first be cleaned with ethyl alcohol and the needle sterilized in a flame.

QUESTIONS

1. What are the five special senses?
2. How has man's inventive mind helped his senses?
3. What are the external parts of the eye?
4. What are the internal parts of the eye?
5. What is the retina and why is it so important to us?
6. What are rods and cones?
7. What is color blindness and what dangers may arise from it?
8. Explain how an image is formed on the retina.
9. What is the blind spot?
10. What six different causes are there for poor eyesight?
11. What remedies are there for such conditions?
12. Can you give several examples of optical illusions?
13. What care should be given the eyes?
14. What are the parts of the outer ear?
15. What are the parts of the middle ear? What tubes open into it from the throat?
16. Can you describe the inner ear?
17. Give examples of different sound waves.
18. Why is it true that a sound wave itself is silent?
19. What happens in the cochlea in order to set up a nerve impulse in the auditory nerve?
20. What are the semicircular canals and what is their importance?
21. What special care should be taken of the ears?
22. How many kinds of sensations does science accept as pure taste?

23. Which parts of the tongue are particularly sensitive? To which tastes are they sensitive?
24. What are the organs of smell?
25. What has to happen in order that an odor may be detected?
26. What four sensations can come from the skin?
27. How can one find the sensitive spots of the skin?

Some things for you to do

1. Find out all you can about Iris, the goddess of the rainbow.
2. By the use of a mirror, watch the pupil of one of your eyes change in size when you come up to a window. Note the effect when someone points the beam of a flashlight toward your eyes.
3. In tabular form, make a comparison of a box camera and your eye, part for part.
4. Examine, if you can, the eyespot on the tip of each ray of a starfish. This is probably the lowest or simplest type of visual organ in the world. Also note the compound eyes on stalks of the lobster, crab, or crayfish. See the curious eyes of the snail, each on a long, flexible tentacle which reverses itself when touched and rolls into the head.
5. Construct an optical illusion.
6. Find out if sound waves travel faster through metal, such as a pipe, or through air.
7. Test your tongue with various substances to find out the sensitivity of various areas to the four substances producing true taste.
8. Experimentally determine heat, cold, and touch spots on a given area of your arm. Make a drawing to indicate the location of each kind of spot.

Think about these!

1. Why is it unnecessary for young persons to use such stimulants as tea and coffee?
2. Can alcohol be digested by the human body?
3. Which of the beverages that you drink have food value?

Words for this chapter

Astringent (ăs·trĭn′jĕnt). As a noun, a drug that puckers the mucous membrane. It tends to cause constipation.
Methanol (mĕth′*ȧ*·nōl). Wood alcohol.
Ethanol (ĕth′*ȧ*·nōl). A name by which grain alcohol is often called.
Ethyl (ĕth′ĭl) **alcohol.** Another name given to grain alcohol.
Toxic. Poisonous.

CHAPTER 17 ——————— UNIT 7

How Do Stimulants and Narcotics Affect Us?

363. How do foods and nonfoods differ? In any study of nutrients and foods, we learn that a food includes anything which may be taken into the body and used to supply bodily heat and energy or to furnish nourishment for making new cells and repairing worn-out parts. Of course real foods are not poisonous or injurious in any way.

Some persons get into the habit of using certain substances which have little or no food value. Some of these substances are positively injurious to the body. Alcohol and tobacco are examples. Older persons may drink tea and coffee because they find them stimulating. They are not foods at all, although the cream or milk and sugar sometimes added to them do have food value. As a rule, a young person has plenty of energy, and he has no need for a stimulant of any kind.

Such nonfoods as tea, coffee, tobacco, and alcohol may be divided into two classes: *stimulants* and *narcotics.*

364. What is a stimulant? Any substance which produces a temporary increase in life energy when it is taken into the body is called a *stimulant.* A stimulant excites the nerves to cause greater activity. Usually it does not add to a person's total energy, but it urges or incites him to spend his energy more rapidly. A whip does not add anything to a horse's energy, but it may make him move faster. In a similar manner, a stimulant whips up a person's nerves and spurs him on to make greater efforts.

365. What is a narcotic? Any substance which deadens the nerves and makes them respond less readily is called a *narcotic.* Its action is opposite to that of a stimulant. A narcotic drug relieves pain and tends to cause drowsiness or sleep. If it is taken in large quantities, it may cause death.

366. What is coffee? The coffee beans, from which coffee is made, are the seeds of an evergreen tree which grows in many tropical and semitropical countries. Arabia, the East Indies, Jamaica, Ecuador, and Brazil are large producers of coffee. One of the chief exports of Brazil is coffee. [See Fig. 17–1.]

The coffee bean is roasted to bring out its flavor and aroma. While the coffee bean does contain a little protein and some oils, yet the soluble part of the coffee bean, which is extracted by boiling water in the making of the beverage known as coffee, contains little or no real nutritive matter. For that reason, coffee can hardly be classed as a food. If we add cream or milk to the coffee, or dissolve sugar in it, then the beverage so prepared will have some food value because of the added fats and carbohydrates.

367. What is the effect of drinking coffee? The active chemical or drug in coffee is known as *caffeine.* It is an active stimulant, and it is sometimes used in medicine because of its stimulating effect. Some headache powders, which contain anti-pain drug, also contain *citrate* of caffeine, which prevents the heart from being too much depressed by the action of the narcotic drugs.

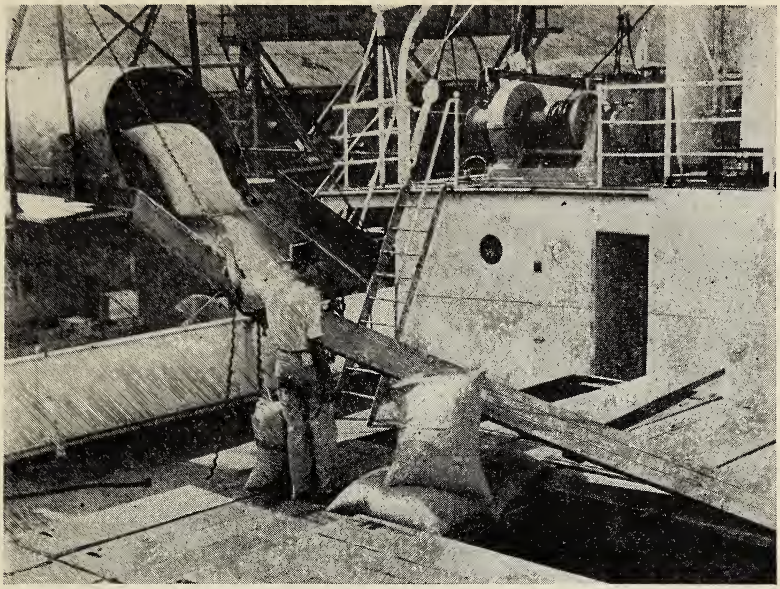


Fig. 17–1. In normal times, a large part of the cargoes shipped from Brazil to the United States consists of coffee. Here you see sacks being loaded into a freighter. (*Courtesy National Coffee Department of Brazil*)

No one drinks coffee because of its food value. Some drink coffee because they find its flavor and aroma pleasing, and because they find it stimulating in preparation for a hard day's work or in overcoming the fatigue from a hard day's work. However, young persons recuperate quickly, and they need not depend upon artificial stimulation. In fact, it is rather doubtful whether coffee gives more than temporary relief for older persons who use it for its refreshing effect.

Coffee affects some persons more than it does others. It keeps some persons awake the early part of the night, if it is taken a short time before bedtime. Some persons find that coffee has a tendency to cause indigestion. Such an effect seems to be increased if the coffee is taken with milk or cream. On the other hand, coffee is rather stimulating to the intestines, and for that reason it serves as a mild laxative.

368. What is tea? The tea leaves of commerce are obtained from a small shrub which is kept trimmed to a height of from three to four feet. It grows in Japan, China, and Formosa, and it has been grown in the Carolinas of the United States. [See Fig. 17–2.] Although the shrub is evergreen, yet the leaves are picked during their growing season. The leaves for *green tea* are cut and rolled without permitting them to ferment. The leaves used for making *black tea* are permitted to wilt and to oxidize to some extent before they are wrapped and shipped to the consumer. The beverage known as tea is made by steeping tea leaves in hot water, or by pouring boiling water through the leaves. The active chemicals in tea are caffeine and an alkaloid known as *theine,* which differs little from caffeine.

369. What is the effect of tea upon the tea drinker? The Americans have been called a nation of coffee drinkers, but it is the Englishman who has the reputation of finding it

FIG. 17–2. From your study of climate, you will know why these tea pluckers on the tropical island of Ceylon wear large hats. (*Courtesy Tea Bureau, Inc.*)

difficult to get along without his tea. It is his custom to stop his work or his play at three or four o'clock in the afternoon to have a cup of tea. It offers a restful period, and the tea is exhilarating, just as coffee is, because it contains a similar stimulating chemical. Tea does not furnish any nutrient for the body, nor can it be called a fuel food. The hot water of which tea is mostly composed is undoubtedly good for the body. The brief interval of rest when drinking afternoon tea is good for the mind.

Tea contains tannin, too, a chemical with *astringent* properties. Hence it has a tendency to retard the action of the bowels and to cause constipation. Some persons find that tea causes headache, and other persons find that it is likely to cause indigestion. Young persons do not need the stimulating effect of tea as a beverage.

370. What are some common narcotics? Probably the narcotic most widely used is alcohol. Of those not so commonly used we may mention opium and the various products made from it. Narcotics are especially dangerous because their use often results in enslaving habits.

371. What are the alcohols? When one mentions the name *alcohol,* most persons think either of wood alcohol or the alcohol made from fruits and grains. To the chemist the name *alcohol* means one of a group of chemicals, all of which have somewhat similar properties or the same nature. What are some of the members of this "family" of alcohols?

a) *Wood alcohol.* Because there are several alcohols, it may be possible to avoid confusion if wood alcohol is called *methanol.* It is a colorless liquid which has a low boiling point and a low freezing point. It is a good solvent. Many substances which do not dissolve in water will dissolve in wood alcohol. Shellac, for example, is a solution in methanol, or denatured alcohol. Methanol is very poisonous. When taken into the body, it may cause blindness and death.

b) *Grain alcohol.* This alcohol, which is made by the

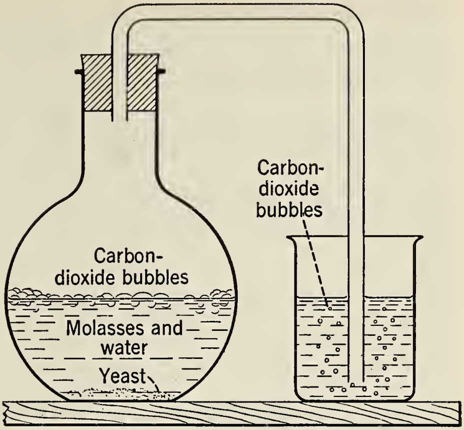
fermentation of fruit juices and grains, is called *ethanol,* or *ethyl alcohol.* It is possible to make 100 per cent ethanol, but what is called *ordinary alcohol* refers to a mixture of 5 per cent water and 95 per cent ethanol. This alcohol is a colorless liquid with a pleasant odor and a sharp, biting taste. It boils at 78° C., and it evaporates fairly rapidly. Because alcohol dissolves many of the active drugs or chemicals found in plants, it is used extensively in pharmacy in making medicine. Ethanol is a very poisonous liquid, so much so that *three ounces present at any one time in the blood of an average-sized adult person is a fatal dose.* That is only a few tablespoonfuls. A few decades ago ethanol was considered a stimulant, especially when taken in small doses. Scientific experiments have shown that in its final results it acts upon the human body as a narcotic.

c) *Other alcohols.* For industrial purposes *butyl* (bū′tĭl) *alcohol* and *amyl* (ăm′ĭl) *alcohol* are both used to considerable extent. *Glycerine* and *carbolic acid* are both alcohols that are widely used. Our further study of alcohols will deal largely with the effects of ethanol, or ordinary alcohol, upon the human body.

372. How is ethanol made? Ripe fruits contain sugar. The yeast plant has the ability to change sugar into ordinary alcohol and carbon dioxide by a process called *fermentation.* The spores of wild yeasts float in the air at all times. Normally, the skins of the fruits keep these spores from coming into contact with the fruit juices inside. When we break the skin of a grape or an apple, then the spores of the yeasts can get inside, and fermentation begins as these spores start to grow. Such fermentation takes place rather rapidly if the temperature ranges from 60° F. to 90° F. The fermentation may continue until all the sugar of the fruit juices is changed to alcohol, but it cannot continue after the amount of alcohol reaches 14 per cent, because alcohol of that strength kills the yeast plants. [See Fig. 17–3.]

Alcohol is made commercially in a similar manner from

FIG. 17–3. If yeast spores get into canned fruit, fermentation soon begins. The sugar in the fermenting juices changes to alcohol, and carbon dioxide is set free. A solution of molasses in water ferments too.



grain. First, grains of barley or rye are permitted to sprout. During the sprouting, a ferment in the growing part changes the starch of the grain into sugar. When the sprout is about a quarter of an inch in length, the grain is mashed and mixed with water and yeast. Fermentation then takes place. Much of the carbon dioxide escapes into the air, or it may be forced into steel cylinders and used for extinguishing fires or for other purposes. The alcohol that is formed remains in the vat mixed with water.

373. What are fermented beverages? Several beverages are made by fermentation in a manner similar to that described in the preceding section. As a rule, they are from 3 per cent to 10 per cent ordinary alcohol, or ethanol. The following are the most common:

a) *Wine.* The different wines are made by the fermentation of the sugar which is found in grapes. The light wines seldom are more than 10 per cent alcohol by volume. Sometimes wines are strengthened by the addition of more alcohol after the fermentation has stopped. Such beverages, which are called *fortified wines,* may be from 18 per cent to 22 per cent alcohol.

b) *Hard cider.* In making this beverage, the juice is first squeezed from apples, and then it is permitted to ferment.

Hard cider contains not more than 8 per cent to 10 per cent of alcohol. Sweet cider does not contain alcohol.

c) *Beer, ale, and stout* are fermented liquors made by the fermentation of such grains as barley. They usually contain from 4 per cent to 10 per cent of alcohol by volume.

374. What are distilled liquors? Sometimes fermented beverages are distilled to produce a liquor which has a higher percentage of alcohol. The fermented liquor is put into a distilling flask, or a *still*, and heated to boiling. Since alcohol boils at 78° C., and water boils at 100° C., it is possible to boil off all the alcohol, condense its vapor, and collect the distilled liquid. It will not be 100 per cent alcohol, however, because some of the water evaporates, too, during the boiling, and it will be condensed and mixed with the distilled liquor. Of course the distilled liquor, which contains *all* the alcohol and *some* of the water from the fermented beverage which was put in the distilling flask, will have a higher percentage of alcohol than did the fermented beverage from which it was made. By repeating the process, it is possible to make by simple distillation a distilled liquor which is 95 per cent alcohol. Distilled liquors are often spoken of as hard liquors.

375. What are the common distilled liquors? *Whisky* is a beverage which contains from 40 per cent to 60 per cent of alcohol. It is made by distilling fermented liquors made from rye and corn and other starchy products.

Brandy, a liquor containing from 50 per cent to 60 per cent of alcohol, is made by distilling fermented liquors made from such fruits as peaches, grapes, cherries, apricots, and apples.

Rum is a beverage which may contain from 40 per cent to 60 per cent of alcohol. It is made by the distillation of a liquor obtained by the fermentation of molasses.

Gin is made by distilling with juniper berries a beverage made by the fermentation of certain kinds of grain. Gin usually contains from 40 per cent to 50 per cent of alcohol.

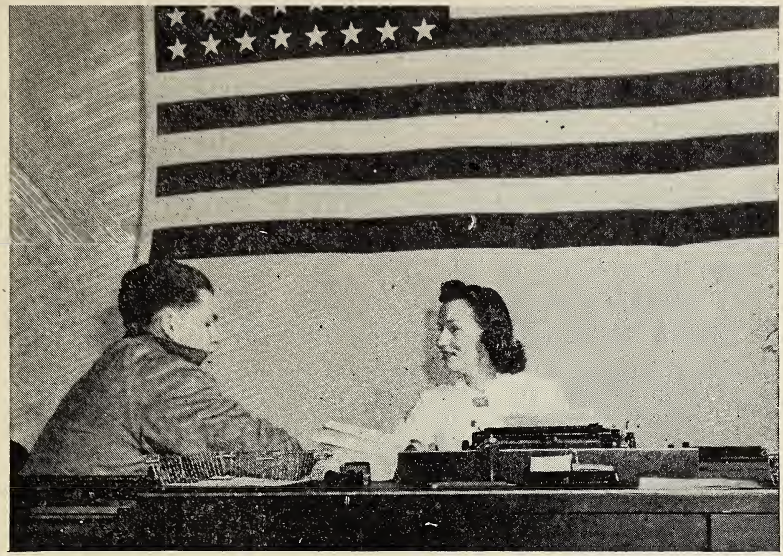


FIG. 17–4. Between 40 and 50 per cent of the young men called to the army in 1940 and 1941 had to be rejected on account of physical defects. Most persons can attain good health by forming good habits. Among such habits, eating *nutritious* food is of major importance. (*Courtesy NYA Photography Workshop*)

376. Is alcohol a food? In only one sense can alcohol be called a food. It is oxidized in the body, and oxidation always produces heat and physical energy. Hence alcohol does furnish some heat to the body.

Alcohol has no nutritive value at all. Hence it cannot repair any worn-out tissues. It has no protein for use in the growth of new cells. It can never be a body builder. The best that can be said of alcohol as food is that it produces some heat energy when oxidized in the human body. [See Fig. 17–4.]

377. What are the objections to the use of alcohol as a food? Possibly you have seen advertisements claiming that "beer is liquid bread." Housewives, too, have been urged to cook with beer. Let us mention several objections to the claims that alcohol is a good food.

a) *Alcohol is a narcotic poison,* dangerously poisonous when too much is taken. Even if a food supplies heat energy, that does not make up for its being a possible source of injury to the body.

b) *Alcohol is a habit-forming drug.* It is greedy for water. It takes water from the tissues of the body and thus causes thirst. To satisfy such an unnatural thirst, the drinker of alcohol is likely to take more and more alcohol.

c) *Alcohol does not give the body a reserve of energy.* It cannot be stored up in the body to supply it with heat and energy. Hence the heat from alcohol is quickly lost. Let us contrast it with starches and sugars. They are changed to *glycogen* (glī′kō·jĕn), which is stored in the liver. Then it is given out to the blood in a steady stream to keep the body warm and to supply it with energy when such energy is needed.

d) *Alcohol wastes body heat.* When alcohol is taken into the body, it causes the blood vessels in the skin to expand. The heated blood from the internal organs then flows into these blood vessels, making the person feel warm. But this condition is only temporary, since the body heat is quickly carried away from the skin into the air. Then the body cools. This may prove to be dangerous if the person is exposed to freezing conditions. The heat energy from true food is not quickly lost.

e) *Alcohol in excess hurts the white blood cells.* True food builds them up.

f) *Alcohol is a very expensive fuel.* There are dozens of real foods which can be used to supply heat and energy at a fraction of the cost of alcohol. Justus von Liebig, a prominent nineteenth-century chemist, tells us that there is as much nourishment in the amount of flour which will lie upon the end of a tableknife as there is in four measures of the best Bavarian beer. There is almost the same amount of heat energy in a ten-cent loaf of bread that there is in one gallon of beer which is five per cent alcohol by weight.

378. How does alcohol affect digestion? It is difficult to answer this question briefly, because the effect of alcohol on digestion varies with different persons, and even more with the strength of the alcoholic beverage itself. Doctor Haven Emerson is an authority on the effect of alcohol upon the human body. He tells us that beverages which do not contain more than ten per cent of alcohol do not have much effect upon digestion. The alcohol in the beverage increases the amount of gastric juice in the stomach, but it is of poorer quality.

Nearly all authorities agree that liquors or beverages which contain more than ten per cent of alcohol do hinder digestion decidedly. If the beverage is sipped slowly during the meal, when there is food present in the stomach, the bad effect of the alcohol is not so great as it is if the beverage is taken on an "empty stomach." Probably one of the worst drinking habits in the United States is that of taking a few cocktails before meals. The use of an alcoholic beverage as an "appetizer" is more likely to retard digestion than it is to aid it. Then, too, the person who gets into the habit of using an artificial "pickup" for overcoming fatigue is likely to increase his tendency to drink alcoholic beverages at other times.

379. How does alcohol affect the liver and the kidneys? If a man applies for life insurance, he is asked whether he uses alcoholic liquors. If he answers "Yes," he is asked whether he uses alcoholic liquors in moderate amounts, or whether he is a heavy drinker. It is rather difficult for a hard drinker to get life insurance, because insurance companies know that the continued effect of alcohol causes certain serious effects which are likely to shorten human life.

The effect which alcohol produces upon the liver and upon the kidneys is rather indirect. We know that the liver is an extremely important organ. It helps to regulate intestinal digestion and nutrition. The question which

is sometimes asked, namely, "How is your liver?" is almost the same as asking the question, "How are you?"

The excessive use of alcohol tends to produce the condition which is known as fatty liver. An alcoholic individual with this condition, who does not get sufficient vitamin B and enough carbohydrates, is likely to develop the more serious disease, cirrhosis of the liver.

Alcohol tends to increase the amount of excretion by the kidneys. Chronic alcoholism tends to injure the kidneys, which are overworked, weakened, and finally fail to perform their normal work properly.

380. How does alcohol affect the nervous system? As soon as alcohol is taken into the stomach, it begins to be absorbed directly into the blood stream. It soon reaches the nerves and begins to deaden or temporarily paralyze them. It seems to progress in at least three fairly well-defined stages:

a) *The stage of exhilaration or false stimulation.* Taken in rather small quantities, alcohol first deadens the nerves which control the size of the capillaries in the skin. The capillaries become enlarged and more blood flows to the skin. The drinker feels a sense of warmth similar to that produced by rather brisk exercise. He acquires a sense of well-being; he usually becomes jovial and talkative; he loses his self-restraint; he sometimes fancies that he is strong enough to whip two or three persons; he thinks that he is witty and clever; he is like a steam engine without a governor; in his exhilaration, he attempts to become the life of the party.

Because the first effect of taking alcoholic liquors causes the drinker to become excited and feel stimulated, alcohol was at one time considered a stimulant. The heart does beat faster for a time, but more feebly. After a few cocktails or highballs, the drinker gets the false idea that he is stronger and that he can work more efficiently. Laboratory tests show that he is weaker after he has been drinking alcoholic

beverages, and that he cannot perform such operations as driving a car or running a typewriter nearly so well as he can when he refrains from using such liquors. [See Fig. 17–5.] This explains why scientists now class alcohol as a narcotic drug.

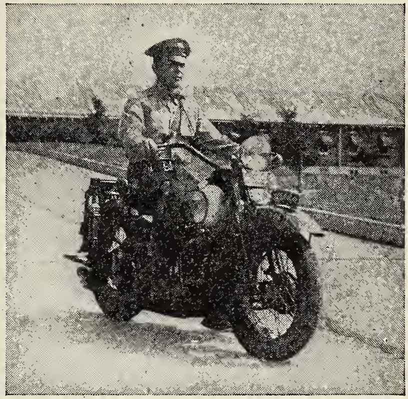


FIG. 17–5. The type of alertness and control shown by this state trooper indicates freedom from dangerous habits of using drugs or narcotics. (*Courtesy New Jersey State Police*)

b) *The unsteady or staggering stage.* As more alcohol is taken into the body and into the blood stream, other nerves become deadened or temporarily paralyzed. The muscles cease to work properly, because the nerves no longer have normal control over them. The drinker begins to see double, and he staggers when he attempts to walk. For some peculiar reason, he loses control of his leg muscles before he loses control of his arms. He can steer a car better than he can operate the foot pedals. He loses his senses of taste and smell. His judgment is greatly impaired.

c) *The deadened stage.* As a person takes more and more alcohol, one nerve after another becomes deadened by the narcotic, and the person falls into a stupor. We say that he is "dead drunk." The nerves which control the action of his heart and lungs are the last ones to be affected by alcohol. If they are not paralyzed and continue to function, the person does not die. His heart keeps on beating, and he continues to breathe. If any person drinks enough liquor

to deaden the nerves which control the life process, then that person will die, poisoned to death by the *toxic* properties of alcohol.

381. What is reaction time? A person drops a quarter from a height of just four feet. He asks you to watch when he releases the quarter, which he is planning to drop, and then to shove your foot under the quarter before it reaches the floor. You can probably do so. It takes just half a second for a quarter to fall four feet. The experiment shows that your time for that particular reaction is just a trifle less than half a second.

Let us use another example. A person is driving a car. A child rushes out into the street from behind a parked car. The driver sees the danger, shifts his right foot from the accelerator to the brake, and pushes down hard upon the brake. How much time is needed for that reaction? If the driver has average reaction time, it will take him about *three-quarters of a second* to become conscious of the emergency and to apply his brakes. [See Fig. 17–6.]

382. How does the use of alcohol affect a person's reaction time? Since the drinking of alcoholic beverages deadens a person's nerves, we would expect alcohol to in-

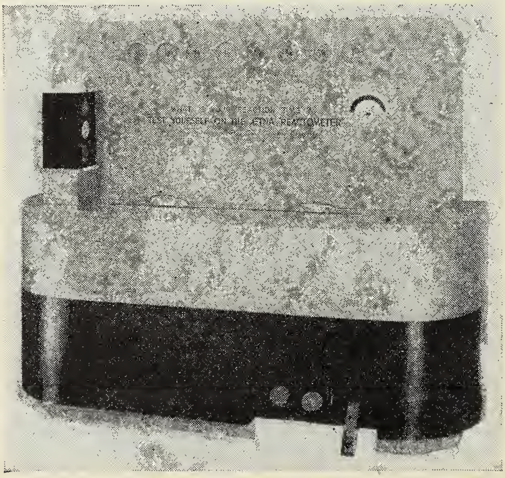


FIG. 17–6. Such a device measures the time it takes a man to remove his foot from the gas pedal, move it to the brake pedal, and push downward. Most persons cannot do this in less than three-quarters of a second. (*Courtesy Aetna Casualty and Surety Company*)

crease a person's reaction time. Experiments carried out by the British Medical Council show that the amount of alcohol present in a couple of glasses of beer or in a couple of cocktails is sufficient to increase the drinker's reaction time decidedly. In some cases it is nearly doubled. Let us suppose that an automobile driver has taken enough alcoholic beverage to increase his reaction time by 50 per cent. How will it affect the safety of other drivers and of pedestrians? Suppose that he is driving his car at 30 miles per hour. A car traveling 30 miles per hour is moving at the rate of 44 feet per second. Forty-four feet is almost twice the width of your school room. Let us suppose that the driver's normal reaction time is three-fourths of a second. If he has to make an emergency stop, his car when moving 44 feet per second will travel on forward a distance of 33 feet before he can apply his brakes, *provided he has not been drinking.* But if he has had enough alcohol to increase his reaction time by 50 per cent, then his car will travel almost 50 feet before he can apply his brakes. *That additional 16 or 17 feet which*

FIG. 17–7. A near accident was prevented from becoming a real accident by the quick reaction time of at least one driver. (*Courtesy National Safety Council*)

his car will travel before he applies his brakes may mean the difference between an accident and a near-accident. [See Fig. 17–7.]

383. What do other authorities say? In a talk on the subject, "Alcohol and Human Physiology," Dr. Benedict of the Carnegie Foundation said: "Inflexible science says, 'Moderate user, keep off! For at least four hours after a dose of alcohol formerly considered permissible, you, as a motor-vehicle operator, may well be considered a menace to society.'"

There is an old saying, "Providence watches over fools, children, and drunken men." Is this saying true? Suppose you ask a nurse or an interne in a hospital about it. They will tell you that from 40 per cent to 60 per cent of the victims of automobile accidents brought to hospitals for treatment, whether pedestrian, passenger, or driver, had been drinking.

From an article in *The National Geographic Magazine* we quote the following: "Many a young airplane pilot has quit smoking to be more sure of passing his rigid physical examinations. Stewardesses and pilots, too, may not take an alcoholic drink within 24 hours before they fly."

384. How does alcohol affect efficiency? Possibly you have heard some motorist say that he drives more skillfully after he has had one or two glasses of beer or one or two cocktails. Certainly the increase in the time it takes him to react to an emergency is a flat contradiction to such a statement.

Helen Wills Moody is reported to have said that the amount of alcohol in a single cocktail was sufficient to take the edge off her tennis game. Men in training for prize fights or for competitive athletic sports almost without exception abstain from the use of all alcoholic beverages while they are in training.

Several series of experiments have been performed at different times to test the effect of alcohol on a drinker's efficiency. The results of such experiments show that as small

an amount as a couple of glasses of beer taken daily lowers an average man's efficiency from 6 per cent to 22 per cent, depending upon his occupation. In one experiment, typesetters were tested. It was found that men who used no alcohol were able to set 14 per cent more type in a day than those to whom a couple of pints of beer or ale were given.

385. Is tobacco dangerous to users? The leaves of tobacco are ground to a powder and used as snuff, mixed with some flavoring material and chewed, rolled up and smoked as cigars, or cut up and smoked in a pipe or in cigarettes. The active chemical in the tobacco, *nicotine,* is a poisonous *alkaloid,* as are also cocaine, morphine, and strychnine. [See Fig. 17–8.] Like alcohol, tobacco is habit-forming. It seems to have a particularly bad effect upon growing protoplasm. For that reason, it is particularly important for boys and girls in their teens to abstain from the use of all forms of tobacco.

386. How does tobacco affect its users? Authorities tell us that the boy who smokes is likely to stunt his growth,

FIG. 17–8. Tobacco plants may grow to a height of eight feet, and the leaves may be longer than a man's arm. (*Courtesy Liggett and Myers Tobacco Co.*)

and to become nervous and lazy. Observations made in one of our large universities showed that a group of non-smokers in the university not only grew more physically during the time in which the observations were carried on, but also had consistently better grades in their studies. Dr. Raymond Pearl, of Johns Hopkins University, carried on many experiments which showed that the use of tobacco is particularly undesirable for any person.

In many cases the use of tobacco seems to have a bad effect upon the heart. Does it seem reasonable to you that the "sucking" of hot tobacco smoke along the throat and into the lungs can really be soothing to the throat or beneficial to the lungs? Is it any wonder that constant smokers are likely to suffer from sore throat and to become afflicted with a chronic cough?

The average human adult eats about one ton of food every year, and during the same period of time he breathes about six tons of air. Tobacco smoke contains many fine particles which certainly must irritate the delicate tissues of which the lungs are composed. A public speaker or a great singer usually refrains from the smoking of tobacco.

Practically all coaches in secondary schools and in colleges forbid their athletes the use of tobacco while they are in training. Professional athletes who are accustomed to the use of tobacco usually abstain from it while they are training for hard contests. Dr. Kellogg tells us that the use of tobacco overworks the heart because it causes the arteries to contract. For that reason it may be the cause of high blood pressure. The heart has to work harder to push the blood through the blood vessels which have been reduced in size.

387. **Why do persons form the habits of smoking and drinking?** Many smokers and drinkers advise a boy or a girl not to form either habit. They admit frankly that both the smoking of tobacco and the drinking of alcoholic liquor in any form are bad habits. They are costly habits, too.

Since these facts are true, one cannot help wondering why so many persons form the habits.

Smoking tobacco and drinking alcoholic beverages are both social habits. One person lights a cigarette and asks you to have one. Perhaps your father is a smoker, and you decide to try it, thinking that it will make you seem more manly. Do you pride yourself upon your leadership? If so, you will find that it takes more independence and will power to refuse when several persons are smoking and the cigarettes are offered to you than it does to accept one. If your will power is too weak to resist, you become like a sheep or a trained seal and follow other persons' directions. [See Fig. 17–9.]

If you have ever smoked a cigarette, no doubt you remember your first smoke. You probably became dizzy, had a bad headache, and were nauseated. Possibly you feared that you might be very ill from the effects of the nicotine in tobacco. After a few hours you recovered. These are common experiences that beginners have. If they try again and again, the body will develop tolerance for the narcotic poison in tobacco, and the habit of smoking is formed.

A young boy or a young girl attends a party. Possibly the

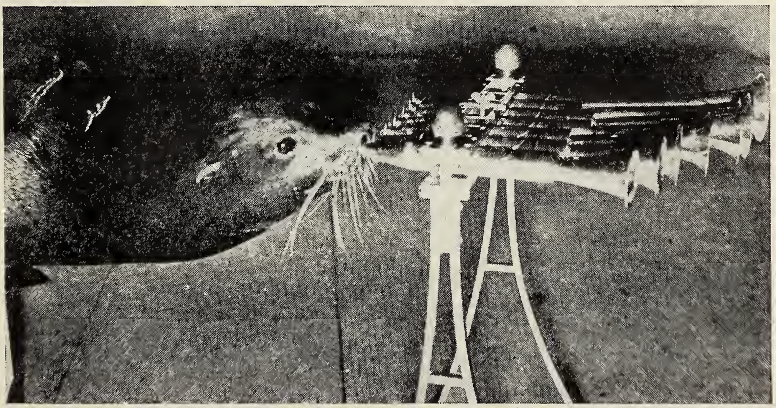


Fig. 17–9. The trained seal cannot use his own judgment. Can you use yours? (*A. F. Sozio from Gendreau*)

hostess serves cocktails containing alcohol. Is it polite for you to refuse? Emily Post is an authority on etiquette. She says that it is permissible for you to refuse such cocktails. She makes a still broader statement. She tells us that any hostess who serves cocktails containing alcohol must also serve nonalcoholic cocktails for those guests who prefer them. You will not be considered a weakling or a coward if you refuse to drink alcoholic beverages, because it takes more courage to refuse than it does to accept.

388. Why are the habits of smoking and drinking difficult habits to break? Boys or girls who begin to smoke in the early teens are likely to smoke more or less incessantly throughout life. Before they become aware of it, the habit becomes firmly entrenched. Some smokers may tell you that they can give up tobacco at any time that they wish to do so, but few of them have the will power to do it. On the other hand, it is no excuse to say that everyone smokes. Many intelligent persons refuse to dull their intellects by the use of tobacco. The idea that the smoking of tobacco enables one to "think like a philosopher" is a false one. It is also true that learning to smoke does not make a boy any more manly. One man was heard to remark that he was giving up smoking because it is becoming so largely an effeminate habit.

Probably no one who takes a first drink of alcoholic liquor expects that he will ever take enough to make him intoxicated. But alcohol, because it has a greed for water, creates thirst. One drink follows another, and each drink weakens the judgment. Soon the drinker has taken too much. It is true that many persons drink sparingly or moderately for years and never drink to excess. Statistics do show, however, that at least three out of every ten who begin to drink will eventually drink to excess.

Both the tobacco habit and the drinking habit tend to grow upon persons because both tobacco and alcohol are habit-forming drugs. They deaden the nervous system and

weaken judgment. The fact, too, that both habits are social, and that "treating around" is a common practice, makes it difficult to break or curb habits of smoking and drinking that are once formed.

389. What are opium and morphine? In China and some other countries the poppy plant is cultivated for the opium it yields. The milky-white juice of the plant is permitted to dry to form opium. When opium is eaten or smoked, it produces a sense of well-being, since it blunts the judgment, the reason, and the memory. The nerves are deadened, and all pain is eased or killed entirely. Drowsiness follows, and the opium smoker is likely to fall asleep and dream lurid dreams. The sleep produced by opium and similar drugs is not refreshing, and each time the drug is used it forges a link in the chain which may later bind the victim with an almost unbreakable habit.

Several narcotic drugs are made from opium. They include *morphine, codeine* (kō′dē·ēn), and *heroin* (hĕr′ō·ĭn). Morphine is much used by doctors to quiet patients who suffer from intense pain. Used in such manner, it acts like an *anesthetic* (ăn′ĕs·thĕt′ĭk) in producing unconsciousness. A druggist is not permitted to *refill* a prescription which calls for the use of the various opiates. Such laws prevent a person who suffers from severe pains from acquiring the drug habit by doctoring himself. No person should under any circumstances use opium or any of the substances made from it without the advice of a physician. Some headache powders contain codeine.

Paregoric is an alcoholic solution containing opium, camphor, and oil of anise. It is useful in checking diarrhea and also to relieve a cough. Parents sometimes get into the habit of giving paregoric to babies in order to relieve pain. It is a rather dangerous thing to do, because opium is a narcotic drug and it is injurious to growing cells. If used too often to relieve pain, it may lead to the formation of the drug habit.

Laudanum, too, contains opium. It is sometimes used in the so-called " soothing syrups " which are given to children to keep them from crying. Small children are particularly sensitive to any form of opium. If a child is really in pain, the parents should call a doctor to find out the cause. Then they should follow his advice. It is a bad plan to keep dosing a baby with a " soothing syrup " so often that he forms the habit of crying until his parents give up and let him have another dose.

390. What is cocaine? Cocaine comes from the leaves of an evergreen shrub which grows in some parts of South America and Java. It is a habit-forming drug, which gradually breaks down the nervous system and makes its user physically unfit. It is popular with drug addicts because it can be easily taken through the nose in the form of a white powder which the users call " snow."

Cocaine has been used as a local anesthetic. More often, such closely related products as *procaine* and *novocaine* are used for that purpose, since they are not habit-forming.

391. What is marijuana? *Marijuana* (mä′rē·hwä′nä) is a very dangerous drug made from a weed which grows in Mexico and in various parts of the United States. [See Fig. 17–10.] It grows wild in city lots and in some cases it is illegally cultivated for the drug which it contains. In some localities it is known as " loco weed," because it is poisonous to horses, sheep, and cattle, and it causes them to act in a manner that makes them seem crazy.

Some unscrupulous persons have mixed marijuana with the tobacco used in making cigarettes. A kind of cigarette known as " reefers " is likely to contain this dangerous drug. It is particularly vicious and dangerous because the person who smokes marijuana may lose his judgment completely, and he may do almost any insane thing. He may even kill his best friend, for no reason at all. Because a person who uses marijuana goes " loco " for a time, perhaps the name " loco weed " is most descriptive.

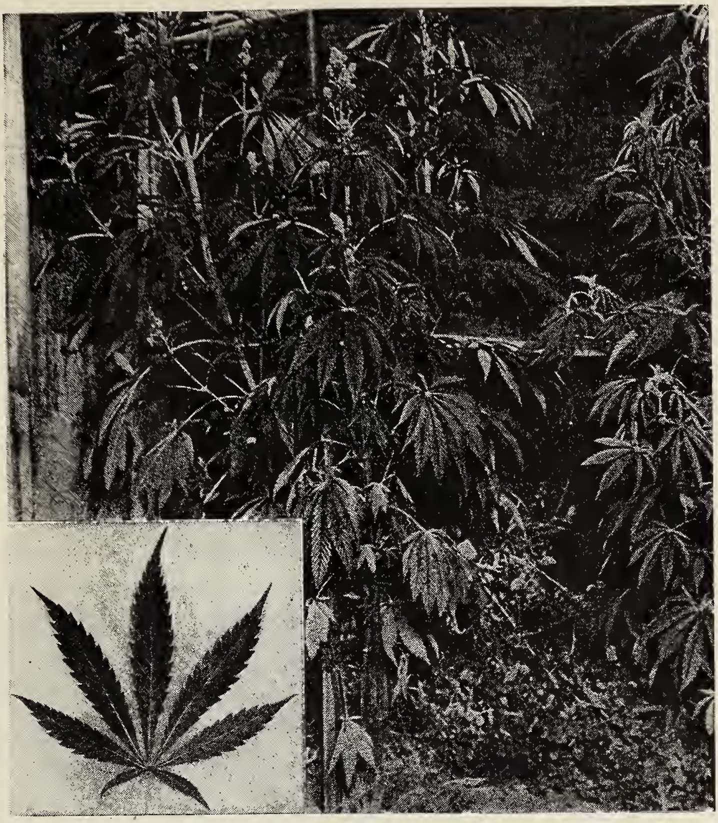


Fig. 17–10. These are marijuana plants, to be avoided or destroyed — not admired or used! (*Courtesy U. S. Bureau of Narcotics*)

392. Is it safe to take patent medicines? Sometimes a person gets sick, possibly because he overeats, overdoes, exposes himself, or fails in some way to take the proper care of himself. Usually rest and a proper diet are all that the person needs for recovery. Probably he does not need any medicine at all.

When disease-producing bacteria are taken into the body, through the lungs or the stomach, or in some other way, then it may be necessary for the patient to have some medicine to help him fight the disease successfully. In such an event, the

proper thing for that person to do is to call a reputable physician to decide what medicine the patient needs. If he takes a patent medicine without a doctor's prescription, he may find that it is not helpful at all, and that it may even be harmful.

393. **Why are some patent medicines dangerous?** Some persons believe every advertisement they read, whether it appears in a magazine, a newspaper, or in an almanac. They are even more likely to believe an announcement made over the radio. One hears a patent medicine advertised over the radio as a remedy for many different diseases. Possibly he sends for a bottle of the medicine and begins to "doctor" himself. He does not know what the medicine contains, or how it will act.

The Federal Pure Food and Drug Law of 1906 (amended in 1940 and called the Federal Food, Drug, and Cosmetic Act) required the manufacturers of patent medicines to put on the label of the bottle the names of all the *dangerous drugs* which the medicine contains. But that provision does not solve the whole problem. The names of the chemicals in the medicine may be printed in small type which the user does not notice. It is possible, too, that the user has no knowledge of drugs or chemicals. He may be ignorant of its dangerous nature, and entirely uncertain as to how it will act.

Many patent medicines contain *opiates, barbitals, luminal,* or *bromides* which merely relieve pain and cause sleep. *Atophan* (ăt′ȯ·făn) and *acetanilid* (ăs′ĕt·ăn′ĭ·lĭd) are rather dangerous drugs which are likely to be present in patent medicines, especially in "painkillers." *Codeine* is present in some headache tablets or powders. Some patent medicines contain so high a percentage of alcohol that they may prove to be habit-forming.

394. **Should you take patent medicines?** If the patent medicine has been prescribed by a doctor, the answer is *Yes.* He probably knows that the active drugs in that medi-

cine are of real value. If the patent medicine reaches you as a sample thrown on your doorstep, or if it is recommended by a friend only, then the answer is an emphatic *No.* It is usually a waste of money, and it may be dangerous, too, to send for a patent medicine that is advertised in your paper or magazine. One must conclude that medicines prescribed by reputable doctors only, and not by those doctors who advertise their own concoctions, are the safest to use.

395. What is meant by a "quack"? An ignorant person who pretends to know a great deal is sometimes known as a "quack." There are some "quack" doctors who have a little knowledge of drugs and medicines, and some knowledge of diseases. Some of them sell medicines which they claim will cure nearly all diseases. Some of them advertise extensively in papers and magazines.

FIG. 17–11. Would you be convinced by the sign or by the label? (*Courtesy U. S. Food and Drug Administration*)

Before the passage of the Food and Drug Law, certain "quack" doctors were accustomed to make some patent medicine, and then advertise it as a positive cure for almost every ill. It is interesting to notice the manner in which their advertising began to change. Some which had read "Positive cure for" a long list of diseases were changed to read "A remedy for" or "Suggested as a remedy for" certain diseases. [See Fig. 17–11.]

Some persons were fortunate enough to see the play "Life with Father." They may recall the experience of one of the sons who decided to earn some money by selling patent medicine. It was bad enough when a neighbor called upon the father to pay for the loss of a dog which was poisoned by the medicine which the boy had sold. The boy explained that the medicine was not for dogs but for humans. Later he was horrified when he learned that his own mother had been poisoned almost to death by some of the same medicine which he had added to her tea. He had read the label and decided that the medicine which he was selling would cure his mother of a slight ailment.

The book called *The Great American Fraud* was published by the American Medical Association. It exposed some of the "fakes" practiced in the advertising and selling of some patent medicines. Some of the medicines had no value at all. Others were positively dangerous. Within recent years, the quality of such medicines has been improved, and many doctors recommend some of them for their patients.

396. Would you be fooled by the following trick? Several years ago a "faker" in a large eastern city used the following ruse to sell his medicine. He handed out to prospective buyers a colorless liquid and a straw. Each one was then asked to use the straw to blow his breath through the liquid. When the liquid turned milky, the faker announced that the test showed that the prospect was a victim of "white plague," or tuberculosis of the lungs. Next the "faker" poured into the milky liquid some liquid from a second bottle.

The liquid cleared up immediately. The clearing up of the milky liquid was supposed to show that his medicine was a "positive cure" for the "white plague." He sold his medicine at a dollar a bottle, and hundreds of persons who had listened to his story and watched his tricky experiments rushed up to buy a bottle.

Suppose you try blowing your breath through a little limewater in a test tube. Does it turn milky? If so, do you think that the test proves you have the "white plague"? Next, add to the milky liquid a little strong vinegar or a little dilute hydrochloric acid. Does the milky color disappear? Can you explain how the "faker" fooled his victims?

QUESTIONS

1. What do you understand by the word *stimulant?*

2. Do you have enough energy to dance or to play football? Do you feel that you need coffee to stimulate you in your work or play?

3. Can you offer any arguments in favor of the afternoon-tea-hour which is so commonly observed in England?

4. What is a habit-forming drug? Can you name several drugs which are habit-forming?

5. Why is the use of marijuana particularly dangerous? Why is the person who tries to smoke marijuana just once, merely for the sake of doing something different, extremely foolish?

6. Suppose a man has a reaction time of three-fourths of a second. He is driving a car at the rate of 45 miles per hour. How far does he travel after an emergency before he begins to apply his brakes? In other words, how many feet does his car travel in three-fourths of a second?

7. Do you think that a person drives a car more, or less, skillfully after he has had a few drinks of wine or beer?

8. Do you think that it makes a boy of fourteen years of age more manly if he smokes cigarettes?

9. How would you answer the question, "Is alcohol a food?"

10. What are the objections to the use of alcohol as a fuel food?

11. Harvey Wiley was largely responsible for passage of the Food and Drug Law of 1906. Why do the American people owe Dr. Wiley a debt of gratitude for his work in reducing the practice of adulterating foods?

12. What is the meaning of the term *narcotic?* Name several drugs and chemicals that have a narcotic effect.

13. Do you think that any young man or young woman really plans to become intoxicated when he or she begins to drink cocktails?

SOME THINGS FOR YOU TO DO

1. Make a summary of all the arguments you can against the use of alcohol as a beverage.

2. Mix a little white of egg with an equal volume of water. To the mixture add about a teaspoonful of ordinary alcohol. What effect do you observe?

3. Drop a live earthworm into a test tube about one-third full of a 20 per cent solution of alcohol. What is the effect?

4. A person spends twenty-five cents a week for cigarettes. How much does his smoking cost him in ten years?

5. Read the article by Gene Tunney, ex-champion boxer, which was printed in the *Reader's Digest* for December, 1941.

Our Bodies Need Constant Care

HAVE you known anyone who built up a strong, healthy body by following the rules of health, and then had that body crippled in an accident?

Unit 8 will give you a picture of the accidental harm that comes to the human body. Every year in the United States about 100,000 lives are lost in accidents. About one-third of these lives are lost in automobile accidents. In addition, about 10,000,000 persons are injured. What can you do about it? If you can learn to think safety and to practice safety wherever you are, this unit will have proved useful in helping you to live a satisfactory life.

It is claimed that in the first year or so of the war that began in 1939, automobiles killed and crippled more persons in England than were killed and injured by bombs dropped from German planes. Do you think that it is time to be careful in avoiding traffic accidents?

In practicing safety, you will need to know how to give first aid. Injuries which cause bleeding must be treated —

sometimes before a doctor can come. Would you know what to do? Could you revive a person who was drowning? First aid must be given quickly, by someone who knows what to do, if it is to protect or save a life.

Think about these!

1. How long would it take you to count $1,000,000, all in one-dollar bills, if you count at the rate of one each second, eight hours per day?

2. In 1940 there were 130,000,000 persons in the United States. About 10,000,000 persons are injured each year in some accident. What are your chances of escaping an accident? How can you improve upon your normal chances?

3. More persons were killed by automobiles during the last ten years than were killed in all the wars in the history of the United States. Do you think it is possible to do anything about it?

Words for this chapter

Gravity. The force which attracts objects toward the center of the earth.

Physique (fĭ·zēk′). The physical structure of a person or of an animal.

Concussion. A severe blow, or the condition resulting from such an impact.

Undertow. The strong undercurrent pull of the ocean away from the shore as the waves break and retreat.

Hazard. Danger.

CHAPTER 18 ——————— UNIT 8

Why "Safety First"?

397. What is the accident picture? Each year the National Safety Council publishes a little volume called *Accident Facts.* It is not a pleasant story or a pretty picture at all. We look only with horror upon the picture of more than 30,000 persons killed in their homes each year by falls and other accidents; more than 40,000 persons slaughtered annually by automobiles; 15,000 or more victims of industrial accidents; 7000 or more persons burned to death annually; and thousands of others killed by farm accidents, destroyed by drowning, or killed while engaging in some kind of sport.

The picture is not improved at all when we look at the 8,000,000 or 10,000,000 persons who are injured accidentally. Some of them suffer for weeks and eventually recover. Some of them become permanent cripples.

398. What do accidents cost? Of course it is impossible to set true value upon human life. Hence we cannot estimate the loss from accidental deaths in dollars. Neither can we estimate the cost of suffering, but we can form some idea of

the cost of medicine, doctors' bills, loss of pay while accident victims are unable to work, and the losses to other members in the victim's family. The Metropolitan Life Insurance Company estimates the total economic loss each year at $3,750,000,000. Your share of that loss is $28 per year, or about fifty cents per week.

The cost of automobile accidents, alone, is believed to be greater than that of operating all the schools in the country. [See Fig. 18–1.]

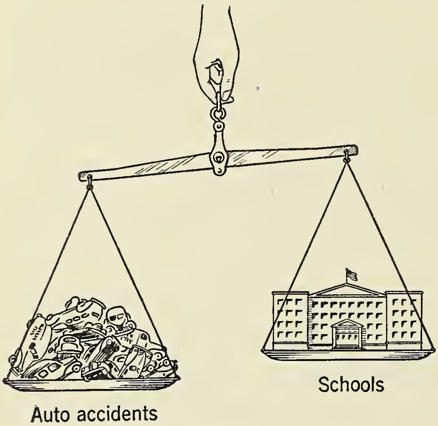


FIG. 18–1. It costs somewhat more than two billion dollars to operate the schools in the United States each year. Automobile accidents cost more.

399. What is the cause of accidents? Before a doctor prescribes a remedy for an illness, he studies the disease and looks for its causes. Before anyone can do much to prevent accidents, he must look for the causes. In our study of accidents, it may be well for us to remember that, "*accidents do not just happen; they are caused.*"

Carelessness is the cause of many accidents. We park a package or a bundle upon the lower steps of a stairway, and someone falls over it. A child fails to put away his blocks, ball, roller skates, or other toys when he has finished his play, and someone trips over them. We rush across the street without looking. We step out from behind parked cars directly into a stream of traffic. Children play in the streets.

Accidents are more likely to happen when we are in a hurry. We dash here and there. We bump into other persons and bowl them over or are bowled over ourselves. It takes time to be careful.

400. How safe is the home? We speak of the home as a sanctuary. We use the expression, "As safe as a babe in its mother's arms," as if to imply that nothing can happen to a person in his home. Yet every year almost as many persons are killed in home accidents as the number killed in automobile accidents. Millions of persons are injured, too, in home accidents. [See Fig. 18–2.]

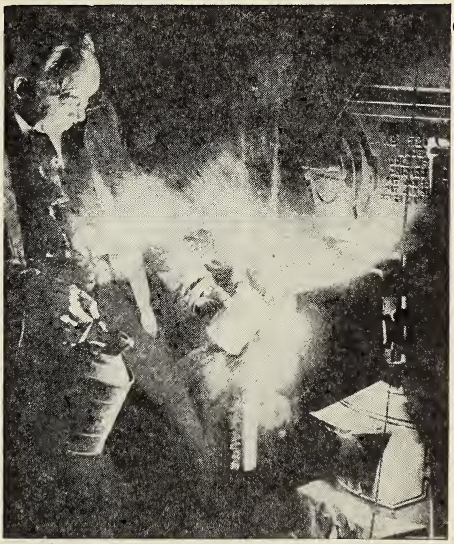


FIG. 18–2. Nearly all accidents which happen in the home are accidents resulting from carelessness. This man is using a flammable liquid — probably kerosene — to start a fire. Such use of kerosene may cause an extremely serious burn. (*Courtesy National Safety Council*)

In our earlier study we have discussed the causes of fires, how fires may be extinguished, what to do in case of accidental fires, how fires caused by electricity may be avoided, and various methods of preventing accidental fires.

In this unit we shall discuss some of the causes of accidents in the home, the streets, the school buildings, and the playfields, and we shall suggest certain ways of preventing them.

401. Falls cause many accidents. At about the age of ten months you got tired of crawling around on "all-fours."

You decided to walk as your mother does. At that time you became familiar with a force which we call *gravity*, a force which pulls objects toward the earth. After many falls, you learned to walk erect. Your falls did not hurt you much, because a young person is elastic and agile. You did not have very far to fall, either.

As a person grows older, his bones become more brittle. For him a fall may be serious, possibly resulting in a broken bone. Old persons are less agile than youngsters, and falls among them are more common. There are many hazards in and around the home which may cause serious falls.

a) *From stools, chairs, ladders, and stepladders.* There are two ways in which a person may increase his stability: He may increase the area of his base by spreading his feet farther apart, or by getting down on all fours. Notice how a football guard increases his stability. This principle applies to stools and other things that we stand on. A four-legged stool is more stable than a three-legged stool. The Great Pyramids of Egypt are so stable that they have stood

FIG. 18–3. The builders of the Pyramids understood the stability of a broad base and a narrow top. (*Philip D. Gendreau*)

for centuries. In choosing something to stand on, select the thing with the widest base. [See Fig. 18–3.] The second way in which a person may increase his stability is by lowering his center of gravity, which is a point in his body at which all his weight seems to be concentrated. If one stands upon a chair, the center of gravity of the combination of his body and the chair is raised. Then he is less stable, and he is more likely to fall. On a tall ladder, as shown in Figure 18–4, the center of gravity is very high. Only a slight sidewise push is sufficient to cause a fall.

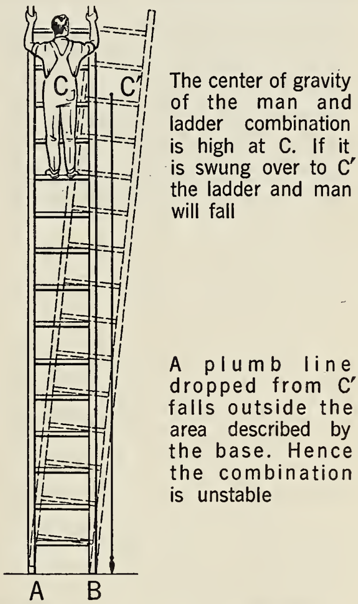


FIG. 18–4. Many workmen are severely injured by falls from ladders. In some cases the base of the ladder slips. If the ladder is too nearly vertical, the workman may fall backward. If the ground at B is softer than at A, the ladder swings over to the position shown by the dotted lines. Then a fall results.

To prevent falls from ladders and chairs, one must be careful not to lean far to either side. He needs to remember, too, that one hits the ground or floor harder if he falls farther. One should also be careful to see that the base of the ladder or chair is firmly placed.

b) *On slippery floors or icy sidewalks.* Linoleum is very slippery when it is wet. Any floor that has just been washed with soapy water is dangerous to walk upon. The person

doing such scrubbing should warn anyone entering the room.

Hardwood floors are slippery, too, especially if they are waxed to make them more lustrous. Many falls result from walking on freshly waxed floors.

The use of small rugs on a waxed floor makes it even more dangerous. One may step on such a rug, feeing sure of his tread, only to find that his feet and the rug both slip from under him. Special rug-anchor material may be bought from almost any department store. Such material is laid upon the floor, to which its rubberlike surface holds firmly. The top surface, upon which the rug is laid, is rough enough to keep the rug from slipping.

Sand, ashes, or rock salt should always be available around the home for sprinkling on icy sidewalks or steps. The first two increase friction and prevent falls. If the temperature is not too low, the rock salt will melt the icy layer.

c) *On stairways.* Many falls result from tripping over material left on the lower steps of stairways. If the stairway is poorly lighted, one may miss the bottom step entirely and get a bad fall. In basements, the bottom steps should be lighted, or at least they can be painted white to make them more easily visible. [See Fig. 18–5.]

It hardly seems necessary to mention the fact that there should be a stair rail, at least along one side of the stairs, to which a person may hold. Out-of-door steps sometimes rot away. A person who steps through such a rotted tread may get a bad fall or may even suffer from a broken leg.

Some stairs have broad treads, and the steps are not too high. Such stairs are easy to climb. Too many architects try to fit the stairway of a house into too small a space. In such cases the risers are high and the treads are narrow. Falls on such steep stairs are too common.

d) *In bathtubs.* The bottom of a soapy bathtub is exceedingly slippery. Hence many persons fall when stepping into a bathtub, or when getting out of one after the bath is finished. A handhold on the side of the tub and a rub-

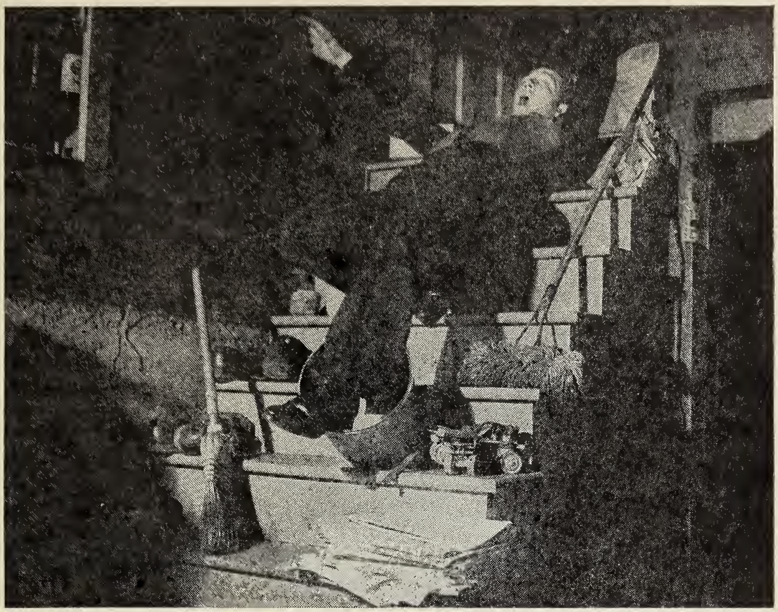


FIG. 18–5. It takes skill to get through the perils of stairways like this. Have you any hazardous stairs in your home? (*Courtesy National Safety Council*)

ber mat for the bottom of the tub are both useful in preventing falls. One needs to remember, too, that the tiled floor of a bathroom is very slippery when the floor is wet.

One may get a severe electric shock by touching a live wire with wet hands. It is more severe if one stands in a bathtub of water and then touches the wire. *No one should ever turn off or on any electric appliance when he is in a bathtub.*

402. **Falling objects may cause accidents.** If we are to prevent accidents, all objects suspended on the walls of the house or the garage must be securely fastened. Heavy pictures must be hung from strong, heavy wires attached to hooks which are securely fastened. Rakes, hoes, and other tools should be kept on hooks which are firmly attached to garage walls. Loose plaster on a ceiling is a menace to one's

safety. The only unlucky thing about walking under a ladder lies in the fact that a bucket of paint or some other object might fall upon your head.

403. How may cuts be caused? When using edged tools, one must exercise great care. Cuts from knives, chisels, axes, hatchets, sickles, scythes, and saws are too common. The ragged edges of tin cans may cause nasty cuts. Even the edges of wrapping paper are sharp enough to cut the skin. It is especially dangerous to whittle or to cut by bringing a sharp instrument toward one's body. The danger from infection from cuts makes it advisable to be exceedingly careful when handling edged tools.

You are attempting to raise a window. Possibly it sticks and it is hard to raise. You attempt to strike the sash with your hand, and accidentally shove your hand through the pane of glass. Possibly a cut wrist is the result.

404. How are punctures and bruises caused? Most wounds of the puncture type are caused by stepping on boards which contains nails, by walking on a garden rake, or by stepping on tacks and needles. It is not uncommon for a seamstress to have a sewing machine needle pass through a finger, or to puncture her skin when using a needle.

Such pointed instruments as an ice pick, a paper spindle upon one's desk, or a lead pencil or pen placed pointed end upward in the pocket, can cause puncture wounds.

Bruises may result from a fall, and a black eye, or worse, may occur as the result of walking into the edge of a door or bumping against a piece of furniture.

405. How are injuries caused during sports? Different kinds of sports produce different kinds of injuries. No doubt many injuries that occur during the various games can be prevented. Let us mention a few of the more common games and inquire why accidents occur.

a) *Football.* We mention football first, because it has the reputation of being a rough game. No one will claim that football is a game for mollycoddles, but it need not be really

dangerous. One opponent of football was heard to admit grudgingly: " It must create plenty of good red blood, or all the bruises, sprains, and scratches would not heal so quickly."

Dangerous accidents occur in football:

When the players do not have the proper equipment for their protection. Such equipment is expensive, and boys who play football on sand lots are generally poorly equipped. [See Fig. 18–6.]

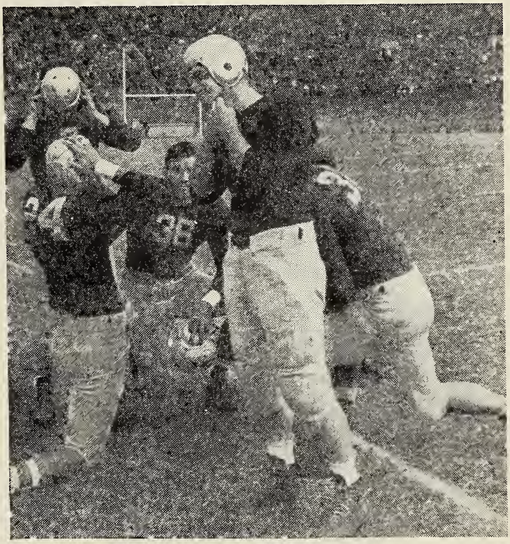


FIG. 18–6. If you plan to play football, you must wear a headguard and a padded suit to protect yourself from injury. Only by great care are football accidents avoided. (*Gregor from Monkmeyer*)

When boys of different ages and sizes play football without supervision. A boy who is 13 years old and weighs 110 pounds should never play football with boys 16 years old who may weigh 160 pounds. Neither should high-school boys ever play against college men, even for practice.

When boys unfit for football enter regular games. Such unfitness may mean poor condition from any cause. It applies to a boy who has a weak heart, a boy who has not been properly trained, a boy who is weakened from a too-recent illness, or a boy who does not have the *physique* for a strenuous game such as football.

When players are unsportsmanlike. No coach who teaches unfair tactics should ever be employed. It is unsportsmanlike deliberately to injure another player. Fortunately, such conduct is becoming more and more uncommon. Strict enforcement of the rules is needed to prevent unnecessary roughness.

b) *Baseball.* The American game of baseball is both a sport and a profession. If one looks over the lists of players on professional teams who are sent to the hospital because of a broken finger, a split hand, a broken leg or arm, a strained muscle, a pulled tendon, a torn ligament, a cut from spikes, or a *concussion* from "bean" balls, he may suspect that baseball takes its toll of injuries too.

It is rather difficult to suggest how such accidents can be avoided. There will not be so many of them if players are in good physical condition. The spirit of fair play will help to reduce them. Proper equipment must be provided for all players if they are to escape injury. The boy who goes behind the plate without a mask is foolish. [See Fig. 18–7.]

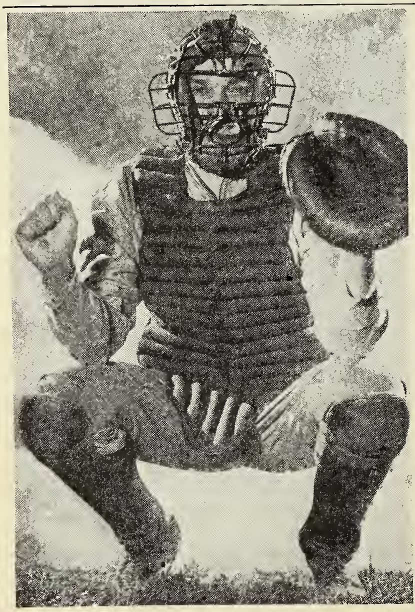


FIG. 18–7. Thousands of persons in this country play baseball. To lessen the possibility of injury, players wear certain special equipment. The catcher in this picture is wearing a mask, heavy padding over his chest and abdomen, and a padded glove on his left hand. (*Courtesy National Safety Council*)

c) *Basketball.* In this game a player is running almost continuously. The game taxes the heart severely, perhaps more so than almost any form of sport except track events. The floor is hard, and players are not padded as they are in football. Unless officials are watchful to see that unnecessary roughness does not occur, bruises, sprains, and even broken legs may occur in a basketball game, and unless slight cuts are sterilized, infection may occur.

d) *Tennis.* This game is often played in hot weather. Boys and girls, too, may play too long and become overheated. Injuries are not very common, but a pulled tendon may result from a sudden leap or spring. The player who leaps over the net, either to recapture a ball or to congratulate his victorious opponent, is really courting injury.

e) *Track events.* In field and track games, injury seldom occurs from bodily contact. Dangers arise from overtaxing the heart or from working too strenuously in an effort to win. Muscle strains and pulled tendons are common injuries.

f) *Swimming.* This form of exercise has become both a sport and a recreation. If you pick up a paper, on a Monday following a week end in summer, you may be appalled at the large number of deaths by drowning. The reason for each tragedy is not hard to find. It usually means that some person has been either careless or foolhardy.

The person who does not know how to swim should never go into water beyond his depth. He must be certain that there are no deep holes into which he may step suddenly. He must not go beyond the ropes in surf bathing, lest the *undertow* pull him beneath the waves.

The person who is a strong swimmer may become careless and do one or more of the following things:

Enter the water too soon after a hearty meal. A muscle cramp may occur to render him helpless.

Stay in cold water so long that a cramp is produced.

Swim out too far from land. He is beyond the reach of help, if he really needs it.

Venture too far out into the ocean, especially at high tide. The undertow is too strong at times for even the strongest swimmer to take chances in the ocean. He may go beyond the ropes. He may go beyond his depth when the lifeguard is absent. [See Fig. 18–8.]

FIG. 18–8. A lifeguard station is a necessity on beaches where many persons are accustomed to swim. The lifesaver must be a strong swimmer. (*Courtesy Long Island State Park Commission*)

Dive into water that is too shallow. A wrenched back or a broken neck may result from diving into shallow water. It is doubtful, in fact, whether it is advisable to dive at all. Anyone who does very much of it is likely to have trouble with his hearing, since the sudden increase in pressure as one goes down into the water is likely to affect the eardrums.

g) *Canoeing and boating.* Many persons drown each year because a canoe or a rowboat is overturned. The person who rocks the boat is not merely a nuisance; he is a possible murderer. He may be a strong swimmer, but other occupants of the boat may not be. The boat may spring a leak. Some person may stand up in the boat and overturn it. The person who is rowing may not be skillful enough with the oars to guide the boat over waves caused by a steamer

or a motorboat. Any of these causes may produce an accident.

If we look at Figure 18–9, we see why it is dangerous for a person to stand up in a rowboat or a canoe. A canoe is

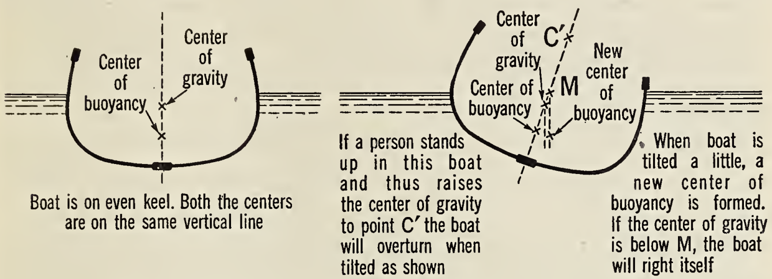


FIG. 18–9. Which is more easily overturned, a canoe or a rowboat? A broad-bottomed boat is safer than either, but harder to row.

very unstable. If only one person paddles, the other person or persons in the canoe should sit perfectly still. It increases the stability if one person lies down in the bottom.

A motorboat should be provided with waterproof cushions which are light enough to serve as life preservers. There is no reason why every rowboat and canoe should not be equipped with such a cushion for every occupant.

h) *Skating.* It is hard to wait until the ice is safe for skating. If a skating pond is controlled, you will not be permitted to go skating until someone has tested the ice to determine whether it is thick enough to be safe. The boy or girl in the country too often has to be his own judge. It is human nature to take a chance at times. Too often a chance on thin ice results fatally. The ice breaks, and the skater may be swept beneath it. It is well to remember that the shallow water near the edge of a stream or pond freezes before the water in the middle of the pond or stream. The ice near the edges may be strong enough to hold you, but too thin in the middle of the pond or stream to support you.

i) *Coasting.* Perhaps you live in a village or city near a long hill covered with snow and ice. Halfway down the

hill a street crosses, and near the bottom there is a second street which intersects the hill. Both streets have heavy automobile traffic upon them. What an ideal place for coasting if the cross traffic can be stopped! But what a dangerous place for coasters unless the cross traffic can be stopped! You will be safe, coasting on such hills *only when the town or city officials can be persuaded to rope off the streets and re-route traffic.*

It is much safer to use a hill where there is no traffic, even if one has to go out into the country some distance to find such coasting.

j) *Skiing.* In recent years the sport of skiing has been taken up by thousands of persons. Skiing affords excellent outdoor exercise. Learners should practice on level roads and streets before they try skiing on hills. Certain dangers are incurred in this sport, especially in localities where the snow is not very deep.

In order to make both coasting and skiing more thrilling, " bumps," or " thank-you-marms," are sometimes built up on the side of the hill. They add to the excitement, but they also increase the dangers, particularly when one coaster or skier dares another to attempt stunts that require superior skill. It is not unmanly or poor sportsmanship to refuse to accept such a dare. [See Fig. 18–10.]

k) *Bicycling.* One wonders why nothing is done for the boy or girl who wishes to ride a bicycle, either for running errands or for pleasure. The pedestrian does not want you to ride on the sidewalks. It is dangerous for him and for you, too. When riding in the streets, you are a constant worry to the drivers of automobiles. No doubt you are afraid of them. In the country, you must ride on the highways, if you ride at all.

What is the answer to the problem? It would not cost very much to run a cinder path or a narrow ribbon of concrete along one side of our highways, to be used by bicycle riders. We build two-lane, four-lane, six-lane, and eight-lane

FIG. 18–10. Skiing is good sport, but few of us have an opportunity to do much of it. How is it dangerous? The skier in this picture has just made a skillful turn. (*Philip D. Gendreau*)

highways for motor cars. Of course the money for such highways comes from license fees for drivers, registration fees from car owners, and taxes on gasoline. Possibly the answer may be a tax upon bicycle riders, to be used to build bicycle paths.

If you feel that you must ride a bicycle, you can usually observe the following precautions:

Ride facing traffic, whenever possible.

Follow a direct route, without winding from side to side, or weaving in and out.

Obey traffic signals, just as automobile drivers are required to do. Crossing a street against a red light is most dangerous.

Always have a light on your bicycle at night, and a warning bell for use at all times.

Avoid heavily traveled streets and rush-hour traffic.

Avoid riding on wet and slippery streets.

406. What kinds of accidents happen in school? A boy or girl is late to class. He or she rushes through the halls

and collides with another tardy pupil who is hurrying to class. One of them is knocked down and strikes his head upon the hall floor. A fracture or a concussion may result.

You are hurrying through the corridor, walking near the walls. A door is thrust open quickly and you are struck by the flat side of the door, or you collide with its edge. In either case, you get a nasty bruise.

School corridors are likely to be very slippery when they are wet. You need to be particularly careful when entering the lower halls into which snow and water have been carried by the trampling of many feet.

Certain classrooms have particular *hazards*. One boy climbed a rope in a gymnasium. He fell and broke an arm. When asked how it happened, he said that he just forgot and let go. You need to remember that "Gravity never forgets." In a chemical laboratory you must observe all the suggestions that are given from time to time for your safety and protection. Almost every machine in a modern shop has all the safety appliances which human cleverness can invent. But you yourself must early learn where dangers lie, and how to avoid them.

Accidents have occurred, in the schoolroom and on the playfield, as a result of throwing objects. The throwing of stones has been the cause of many injuries, often resulting in the loss of an eye. Frozen or ice-covered snowballs are dangerous. Pupils have been pushed through glass doors and have suffered cuts. Courteous and fair-minded pupils do not trip other pupils who are passing through the corridors. Only a thoughtless, careless pupil will push a child's face down into a fountain from which he is drinking and possibly knock out one or more of his teeth.

407. Do dangers lurk in the country? Whether you live on a farm or merely spend your summers in the country, you must remember that accidents are not lacking even in quiet country fields and byways. Farm animals to be avoided or watched carefully include the bull, the boar, and the ram.

Even horses may be vicious at times. Any female animal is dangerous when she feels the need for protecting her young. A startled animal may injure you by striking out in his own defense. You need to be able to recognize poisonous snakes and to learn where they are most likely to be found. The rattlesnake, the copperhead, and the moccasin are the only common poisonous snakes found in the United States.

If you are allergic to poison ivy, you must learn to recognize the plant and then to avoid it. If you are likely to contact poison ivy, you may avoid being poisoned by it by covering the exposed parts of your face, neck, hands, and arms with a 5-per-cent solution of ferric chloride or by using a freshly made mixture of sodium peroxide and face cream. If these chemicals are not available, rub a wet cake of laundry soap over the exposed part of your skin. Poison sumac is dangerous to most persons. The pollen of many plants may cause hay fever. Possibly you may avoid certain plants, especially when their pollen is ripe.

Falls occur in the country, too. Possibly there is even more opportunity for them here than in the city. Boys and girls are fond of climbing up on the beams in barns and of climbing up into apple trees or other fruit trees.

408. Do you know how to cross streets safely? Because you have been crossing streets for some years, this question may seem foolish to you. But do you know of someone who has been driving a car for several years and still does not drive safely or well? If you watch other pupils who are crossing a street, you will probably see the following careless things being done again and again:

a) A pupil crosses the street without even glancing either to the right or the left. He should look to his left first, then to his right, and then to the rear for the car rounding a corner behind him.

b) A pupil crosses the street with his head hidden in an umbrella. The police call accidents to such persons, "Ostrich accidents."

c) A pupil crosses against a red light. He is more than doubling the probability of being run over.

d) A pupil crosses a street between intersections. Many fatal accidents to pedestrians occur when they are crossing between intersections.

e) A pupil steps from behind a parked car and starts across the street. He is inviting danger.

f) Three pupils start across the street without looking. They hear a car approaching. One of them continues across. A second one stands still. The third one turns back to the curb. Do you not agree that the motorist's chance of hitting one of them is fairly good?

g) A pupil may race to beat a car to an intersection. Many races are lost, and some of them are ties.

h) Some pupils dilly-dally when crossing a street. They appear to tempt a motorist to hit them. They need not run, but they should walk briskly.

i) Some pupils jaywalk, or cross streets diagonally. Such practice may save a few steps, but it also increases their chances of riding in an ambulance. [See Fig. 18–11.]

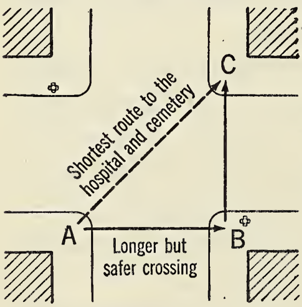


FIG. 18–11. Many accidents occur when pedestrians cross streets. Some persons are foolish enough to cross diagonally. Their chances of having an accident are increased. Can you tell why?

j) Many pupils do not allow enough time for crossing safely. Let us solve a problem in simple arithmetic. Suppose you have to cross a street which is 30 feet wide. Walking briskly, you cover 6 feet per second. It will take you 5 seconds to cross the street, or 2.5 seconds to reach the middle of the street. [See Fig. 18–12.]

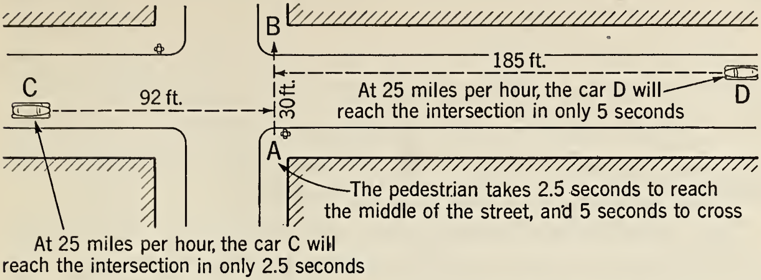


FIG. 18–12. Did you ever time another pupil to find out how many seconds it takes him to cross the street in front of your school?

As you look to your left, you see a car coming, at a rate of 25 miles per hour. That means the car is traveling about 37 feet in one second. How far distant must that car be if you are to reach the center of the street safely, provided you do not run, and assuming that the driver of the car is too self-centered to slow down or stop? When we multiply 37 by 2.5, we get about 92 feet. There are from 10 to 20 blocks in one mile. Such blocks vary from 264 to 528 feet in length. If you are to cross safely, *the approaching car must be at least one-third of a short block away when you start across.* The car is traveling *more than six times as fast as you are.* Some safety experts calculate that a pedestrian takes one step while a car in city streets travels its own length.

But in 2.5 seconds you are only halfway across, and there may be a car coming from the opposite direction, from your right. Such a car should be at least two-thirds of a block away when you start across.

If traffic is moving at 30 miles per hour, and the street is from 40 to 50 feet wide, then one should never start across if an approaching car from his left has entered the block.

409. **Actions persons may regret.** A delivery truck stops for a red light. Two or three boys rush out and climb upon the rear of the truck. After riding a few blocks, they hop off while the truck is moving rapidly. They not only run the risk of being injured by a serious fall, but they are in great

danger of being run over by a car which may be following.

It furnishes a thrill to loop one end of the rope of your sled to a motor vehicle. You get a fast ride when the car moves away rapidly. The speed may become so great that you may be injured by being thrown off, and then be run over by another car. Such thrills cost lives.

Boys who deliver newspapers sometimes ride on the running board of a car, hopping off to deliver the paper, and jumping on again while the car is moving. In some states riding on the running board is illegal; in all states it is dangerous.

Bicycle riders sometimes get a free pull by holding to the rear corner of a car as they steer their wheel with one hand. Explain why this practice is dangerous.

No doubt you have seen boys edging out into street traffic in efforts to " thumb " rides. One such hitchhiker was insulted when an elderly lady asked her driver to stop. She offered the boy a nickel for car-fare. " I'm no beggar! " he said in an injured tone. Hitchhikers are a menace to themselves. They sometimes force a driver to run into another car to avoid hitting them. Several states have passed laws making it illegal to stand in the street and solicit rides. Every driver should use the old Roman " thumbs down " when he encounters a " thumbs-up " pedestrian. The driver is legally responsible if he asks you to ride with him, and there is an accident in which you are injured. Drivers have been held up and robbed by hitchhikers they foolishly picked up.

From the point of view of the person wanting a ride, the driver may seem selfish. Look at it from the following point of view. Suppose that you are a hitchhiker. The driver you ask for a ride may be a poor one. He may have been drinking. He may have an accident. You may be so severely injured that you become a cripple for life. It is even possible that the driver may plan to kidnap you.

Questions

1. Why do persons sixty years of age or more have more falls than persons from ten to thirty years of age?

2. Why is a person sixty years of age, or older, more likely to be injured by a fall than is a young person in his teens?

3. Make a list of what you consider the chief causes of accidents.

4. What are some of the real hazards in your own home?

5. Which of the hazards mentioned in question 4 can you do something to lessen? Explain in detail.

6. Do you shovel the snow from your sidewalks in winter? If your walks become icy, what do you do about it?

7. What is your favorite sport? Do you play it well? What are the most common hazards from that sport?

8. Would you like to have a brother of yours play football? Give some reasons for your answer.

9. Perhaps you enjoy swimming. What rules should govern your swimming habits?

10. Did you ever see a canoe-tilting contest? If so, what does it teach you about the stability of canoes?

Some things for you to do

1. Try to find out the minimum thickness of ice that is safe for one person to skate upon.

2. Ask your principal whether there have been any accidents in your school the current year. If so, try to find out how many there were and what caused them.

3. Make a list of all the careless things you see pedestrians do in one week.

4. Make a list of all the careless things you do in one week. How many of them have resulted in near-accidents?

Think about these!

1. If someone faints, what should you do?

2. If you are with a group of friends on a field trip, and one member of the group is bitten by a rattlesnake, what should you do?

3. If you are alone with someone who cuts an artery in his wrist, how could you keep him from bleeding to death?

Words for this chapter

Tourniquet (toor′nĭ·kĕt). A bandage which can be tightened by twisting, sometimes by means of a stick; it is used to control bleeding, especially that from a severed artery.

Gangrene (găng′grēn). Decay of bodily tissue.

Anaerobic (ăn·ā′ĕr·ō′bĭk). Able to live without free oxygen.

Cauterize (kô′tĕr·īz). To burn the flesh with a hot instrument or a chemical, as is done in treating the bite of a dog.

Rabies (rā′bĭ·ēz). The disease caused by the bite of a "mad" dog or other animal that is suffering from hydrophobia.

Prone. Face downward.

Convulsions. Spasms in which the muscles contract strongly.

Coma (kō′mȧ). A deep sleep, in which a person is completely unconscious. The person appears as if dead.

CHAPTER 19 ______________ UNIT 8

How Can We Practice First Aid?

410. How should cuts be treated? Cuts may occur on any part of the body, but they occur most frequently on the fingers, toes, hands, wrists, and ankles. If the cut is not very large or very deep, it is best not to try to stop the flow of blood. Letting it bleed for a few minutes helps to cleanse the wound. Then an antiseptic may be applied. [See Fig. 19–1.] It is probable that no better antiseptic can be found than tincture of iodine. It stings slightly, and it discolors the skin, but these effects are mere trifles. A number of other antiseptics may be used. Many of them are on the market. Observe this caution. A 2-per-cent solution of iodine may be used. Such a solution consists of iodine dissolved in alcohol. If the bottle is left unstoppered, the alcohol evaporates, and the tincture becomes much stronger. The common 7-per-cent solution may be safely used, too, but it must not be applied a second time, and it should dry before the wound is bandaged. Otherwise, the iodine may blister the skin, and such blisters are exceedingly painful and irritating. (If no iodine is available, the wound may be washed in warm soapy water.) After a drop or two of iodine

FIG. 19–1. A complete first-aid kit is a good thing to have in your home. (*Courtesy Johnson and Johnson*)

solution has been applied with a glass rod or stick tipped with sterilized cotton, and the iodine has been permitted to dry, the wound may then be covered with a sterile dressing or compress, which can be held in place firmly by a bandage or a strip of adhesive tape on either side of the wound. A wound treated with iodine should be bandaged *loosely* or not at all.

411. What is infection? Bacteria are present upon the skin at all times. If the skin is unbroken, the bacteria cannot get into the blood at all. But the slightest scratch, cut, or prick of the skin opens the door for them to enter. Then they may begin to multiply rapidly. Unless the white cells of the blood destroy them very quickly, or unless they are killed by means of some antiseptic, the bacteria will cause the formation of pus. Certain types of bacteria may get into the capillaries and the lymphatics and cause what is called blood poisoning.

412. What should you do when an artery is cut? In such a case the bleeding will be profuse, and the blood will flow in jets or spurts. You must act quickly to prevent un-

due loss of blood. You may first try applying pressure with your fingers upon the artery, between the wound and the heart, and at a place where the artery is near the bone. For bleeding in the hand or arm, the pressure should be applied just beneath the upper end of the biceps muscle, against the bone on the inner side of the arm. [See Fig. 19–2.] For

FIG. 19–2. It is not difficult to locate the large arteries beneath the large muscles, and to apply pressure in order to check bleeding. (*Courtesy U. S. Bureau of Mines*)

bleeding of the face, pressure may be applied against the artery which lies just in front of the ear; or to check the flow of blood to the lower part of the face or to the neck, the pressure may be applied along the jawbone, or against the first rib just behind the inner part of the collar bone. For bleeding from the foot or leg, pressure may be applied in the groin with the edge of the hand. Such pressure will reduce the flow of blood by pressing the artery against the inner side of the hip bone.

413. Shall you use a tourniquet? When it becomes difficult to control bleeding by pressure with the hand or fingers, a *tourniquet* may be used, provided the wound is on one of the extremities — a leg or arm, for example.

One must be careful in the use of a tourniquet not to shut off circulation too long. After about fifteen minutes, the tourniquet must be loosened. If the bleeding has stopped, let the tourniquet remain in a loosened condition, apply sterilized gauze to the wound, and bandage it securely. The gauze helps to some extent in the formation of a blood clot.

If upon loosening the tourniquet the blood starts to flow again, it may be tightened a second time. When the circulation is shut off from any part of the body for too long a time, that part dies and *gangrene* begins.

414. How can you make a tourniquet? A rubber band a couple of inches wide makes an excellent tourniquet. A strip of cloth of about the same width may be used. It is even possible to make one from a pocket handkerchief by folding it diagonally, and then into a wide band. In an emergency a strip of cloth can be torn from a shirt.

To use a tourniquet, place a folded pad over the artery. Wind the strip of bandage loosely twice around the arm, for example, and tie a half-knot so that the knot rests over the pad. Then you may place a stick six or eight inches long, or a pencil, upon the half-knot, and then tie a complete knot above the stick. Pressure is applied by twisting the stick. Do not exert more pressure than is needed. Be sure that the pad and knot are directly over the artery, and between the wound and the heart. [See Fig. 19–3.]

FIG. 19–3. The proper way to apply a tourniquet. Too much pressure, or too long continued pressure, must be avoided. (*Courtesy U. S. Bureau of Mines*)

415. How do you stop bleeding from a vein? The same pressure-method one uses to stop bleeding from an artery may be used to stop bleeding from a vein. From a vein, the blood flows evenly. In this case, however, the pressure is applied beyond the wound, or farther away from the heart than is the wound itself. Less pressure is required to stop bleeding from a vein than from an artery. It may be suffi-

cient to make a compress, apply it directly to the wound, and then hold it firmly with a bandage. One may even apply pressure with the hand to the bandage until a clot of blood has formed.

416. **Why may puncture wounds be dangerous?** Nails, pins, needles, icepicks, and slivers are the most common causes of puncture wounds. If the wound is from a sliver or a thorn, the sliver or thorn must first be removed. Some bacteria will not grow unless oxygen is present. One type does not grow or multiply when oxygen is present, although they can live as spores. Such bacteria cause lockjaw, or *tetanus.* Then *anaerobic* bacteria may be pushed down deep into a puncture wound by the instrument causing the puncture. This deep wound may heal at the surface, thus shutting off the oxygen from the bacteria underneath, and permitting them to multiply greatly. Such germs may also be carried beneath the skin by powder grains from exploding firecrackers or blank cartridges.

417. **How do you treat a puncture wound?** Usually a puncture wound does not bleed freely. You may first encourage bleeding by gentle pressure upon the tissue around the puncture. Then try to work iodine solution down into the puncture wound. Be sure that the wound does not heal at the surface before it has healed underneath.

A doctor should always be called to treat a puncture wound. He may cut the top of the wound to stimulate bleeding and to permit it to heal from the bottom upward. He may give tetanus antitoxin to prevent lockjaw, a disease which may be easily prevented but one that is difficult to cure after it has developed.

418. **What can you do for burns or scalds?** We usually think of a burn as an injury caused by dry heat, and of a scald as being caused by a hot liquid or by steam. The effect is much the same in either case. The treatment depends on the depth, or *degree,* to which the tissue is burned. Even a deep, local burn of a small area is not likely to be so serious

as a more shallow burn which affects a large skin area. We may inquire what is meant by different *degree* burns and how to treat each one.

a) *First-degree burns.* Such burns are characterized by more or less pain and a reddening of the skin. A paste of baking soda may be applied to the burned portion to reduce the pain, or a dressing of olive oil may be used. A burn ointment may be applied to a sterilized gauze, which is then applied to the burn and fastened in place by a bandage.

b) *Second-degree burns.* Burns of this degree are more severe. The skin is blistered, and there may be danger from infection. Several layers of sterile gauze may be applied to the burn. The gauze is then moistened with warm, *sterile* water (water free from bacteria), to which baking soda has been added. A bandage is then applied to hold the gauze in place.

Most first-aid kits contain picric-acid gauze for use on burns. For use, several layers are applied to the burn and

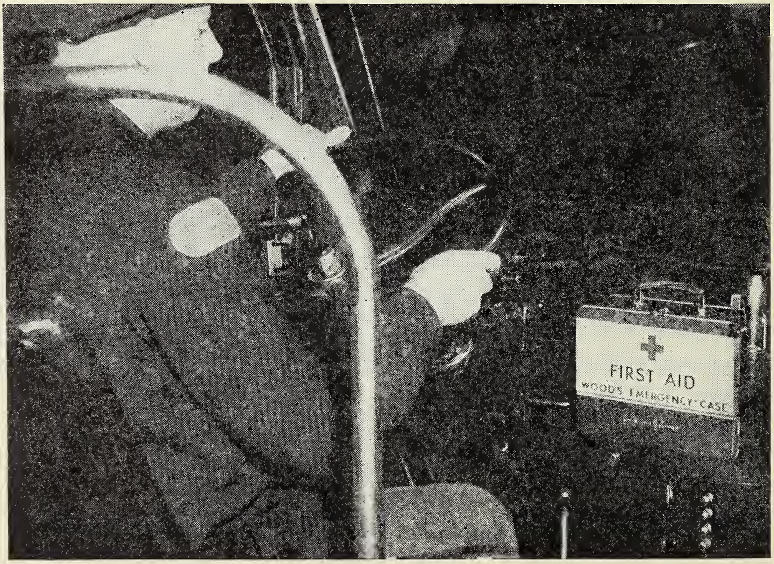


FIG. 19–4. Why do you think that a first-aid kit is part of the equipment of a bus? (*Courtesy Johnson and Johnson*)

then moistened with warm, clean water. *Tannic acid* preparations may also be used. Tannic acid is a fluffy powder which is easily soluble in water. [See Fig. 19–4.]

c) *Third-degree burns.* In such burns the skin and the tissue beneath it may be burned, sometimes to a crisp. They require a long time for healing. Many such burns occur in various industrial plants.

A 5-per-cent solution of tannic acid is extensively used in treating such burns. A freshly prepared solution of tannic acid may be sprayed upon the burn. It is even better to use several layers of gauze and to moisten them with tannic-acid solution. Tannic-acid jelly, which can now be bought, may be spread upon gauze and applied to the burn.

419. How can sunburn be prevented, and how is it treated? The skin of most persons is sensitive to the hot summer sun. One can avoid sunburn by developing a coat of tan by moderate exposure of the skin to the sun's rays during the late spring and early summer. Cocoa butter and olive oil are sometimes used by bathers to prevent sunburn, and to develop a coat of tan. Tannic acid applied to the skin is said to act as a preventive of sunburn. The sun's rays may cause either a first-degree or a second-degree burn. Such injury to the skin is more serious than many persons believe. It may cause not only much discomfort, but also rather serious illness. [See Fig. 19–5.]

Olive oil, cocoa butter, or dressings made from sterile gauze and tannic-acid solution may be used to relieve sunburn. Tannic-acid jelly has been widely used too.

420. How shall one treat frostbite? It is not uncommon for a person in Canada or the northern part of the United States to meet someone on the street and say: "Sir, your nose looks whitish." The little particles of ice form beneath the skin before a person is aware of the fact that his nose, his ears, his fingers, or his toes are being nipped by Jack Frost. As the water in the cells expands upon freezing, it tears the cell walls and may injure the tissues severely.

FIG. 19–5. The skin burns easily when it is wet. Staying in the water too long or lying on the beach in the hot sunshine may cause a dangerous sunburn. (*Ewing Galloway*)

More severe freezing may kill the cells and gangrene may result. Care must be taken to prevent children from handling " dry ice."

The old method of rubbing the frozen part with snow is not a good one, since it injures the cells more severely. The frozen tissue should be thawed out *slowly* by the use of cold water or by holding snow or ice on the parts. Do not use warm water or thaw out frozen parts by standing near a fire. The nose or ear may be covered with the hand to thaw the frozen parts slowly, and frozen fingers may be held in the armpit.

421. What does one do if bitten by a dog? The wound caused by the bite of a cat or a dog may be a puncture or a laceration. Such bites may be particularly dangerous, because infection may occur. One first washes the wound, preferably with running water, to wash away the saliva which may contain germs which can cause infection. The first-aid treatment that is advised after the washing consists of treating the wound with iodine or with some equally satisfactory antiseptic. Then the wound is dressed as if it were an ordinary wound.

A doctor should be called at once. He may *cauterize* the wound, and possibly he will give the Pasteur treatment to avoid *rabies,* or *hydrophobia,* or send the victim to a Pasteur institute to have such treatment given. This treatment is usually followed only when the dog show evidences of rabies. In such cases the dog is killed immediately to prevent other animals and persons from being bitten. In all cases, the dog or other animal should be kept under observation for at least ten days. If he shows no symptoms of rabies within that time, he may be set free. When no symptoms are shown by the dog or other animal, the person who was bitten need not take the Pasteur treatment. Some authorities, however, think it is best not to wait that long, but that the Pasteur treatment should be given earlier, especially if the person is bitten about the face.

422. Do you know how to recognize poisonous snakes? The body of the very small coral snake, which is found in certain southern states, is encircled by black, yellow, and red bands. This poisonous snake, which is rare even in its own normal habitat, is easily identified. The *vipers,* which include the copperhead, the rattlesnake, and the moccasin, are the only other poisonous snakes to be found in the United States. The *rattlesnake* is rather easily identified by the diamond-shaped markings on his back, by his triangular-shaped head, and by his rattles. He usually sounds a warning rattle before he strikes, but he does not always do so, and he may strike immediately after he has sounded the warning rattle.

The *moccasin* gets the name " cotton mouth " because of the whitish appearance of the inside of his mouth. This snake is found in some of the southern states near streams and in swampy regions. The *copperhead* has a copper-colored head, a hazel-brown or golden body, with dark copper bands on a background of bright copper color, and a flattened, triangular-shaped head. Because of its resemblance in color to dead leaves, this snake is particularly dangerous

to hikers in the autumn. It is supposed to give out an odor like that of a cucumber. This snake is also called by such names as "pilot" and "red adder." He is likely to be sluggish in his movements, but he bites without warning.

423. What precautions should one take? About three-fourths of all snake bites occur on the legs, and nearly all the rest are on the arms or hands. These facts give us the answer to our question. By protecting the legs with high shoes, boots, or leggings, one is fairly safe when walking through a place that may be infested with poisonous snakes. One must never use his hands when climbing over rocks, or thrust his hands into places that are hidden by foliage when he is picking berries or wild flowers.

424. How should you treat a case of snake bite? The patient must lie down and keep quiet. You should tie a bandage or handkerchief around the limb just above the bite, which will look like two tiny punctures of the skin, close together. Such a bandage keeps the blood from flowing through the veins toward the heart, but it should not be tight enough to stop the flow of blood through the arteries. After sterilizing a razor blade or the blade of a sharp knife in alcohol, iodine, or a flame, you may stimulate bleeding by making a cross cut about a quarter inch deep for a quarter inch in each direction over the puncture wound. Of course you must be careful not to cut an artery or a large vein. The blood will help to wash the *venom* (vĕn′ŭm), or poison, from the wound. If a tourniquet is used, it should be applied at a little distance from the bite, on the side toward the heart, and it must be loosened at intervals.

The venom may be sucked from the wound by the mouth and then spat out, if there are no breaks or scratches in the mucous membrane in the mouth. A rubber bulb, attached to the small end of a glass funnel, or with suction cups of various shapes, is a part of some first-aid outfits for use against the bites of poisonous snakes. The use of such a suction cup should be continued for some time. It is no longer the

FIG. 19–6. Forcing the poison from the glands of a rattlesnake is called "milking" the snake. The venom is used to make antivenin, the surest antidote for snake bite. (*Courtesy Hiram Jefferson Herbert*)

practice among physicians to give alcohol to snake-bite victims. It is almost certain to do more harm than good. If the serum known as *antivenin* is available, it should be given to the victim as soon as possible.

425. What is antivenin? Scientists have succeeded in making from rattlesnake venom a serum which is useful in treating persons who have been bitten by one of the vipers. There are snake farms where rattlesnakes are grown and, at intervals, milked of their venom. [See Fig. 19–6.] It is better to have a doctor administer antivenin, although one skilled in its use may give it in an emergency by injecting it into the tissues around the bite.

426. Foreign matter may get into the eye. If you buy eyeglasses, you usually find in the case for them a piece of soft cloth for use in wiping the dust from them. To remove the dust from the lens of a camera or microscope, you use soft lens paper. Are you as careful of your eyes? Particles of dust, cinders, sawdust, sand, or bits of metal may get into the

eye accidentally. Usually they do not penetrate the eyeball itself, but they are most irritating. Do you rub the eye roughly and grind the particles into the tissues of the eyeball? That is sometimes done. If you rub the eye at all, it must be done very gently and always toward the inner corner of the eye. The tear glands are located above the outer corners of the eye. Their purpose is to secrete tears which flow across the eyeball and into the tear duct which leads to the nasal cavities. Thus they wash the eyeball.

Usually an increased flow of tears will wash away dust particles. A boric-acid eyewash may be used to help the tears. By pulling outward and downward upon the upper eyelid, you stimulate the flow of tears and you may also help to dislodge the foreign particle that may be sticking to the eyeball.

If you push downward upon the lower eyelid while the eye is rolled upward, you may be able to see the particle of foreign matter and remove it by brushing lightly toward the nose with one corner of a fine, clean handkerchief. Never try to remove such a particle with any hard instrument.

If acids, alkalis, cement, mortar, or other chemicals get into the eye, large quantities of water must be used to wash out the excess chemicals as quickly as possible. If foreign matter becomes embedded in the eyeball itself, call a doctor at once.

427. What should be done in case of fainting? If you feel faint, lie down at once, or bend forward until the head is between the knees. Thus you avert a fall which may be dangerous. If another person feels faint, induce him to lie down. Keep the head low and lift the feet and legs. Tight clothing should be loosened. A bottle of smelling salts held near the nose will usually cause a return of consciousness almost at once.

Fainting is caused by lack of blood in the brain. Such a condition may be brought about by fatigue, hunger, emotional shock, or a continued stay in a crowded room. If the

fainting person does not regain consciousness rather quickly, after the use of the smelling salts or by the sprinkling of cold water in his face, you should cover him to keep the body warm, and then call a doctor.

428. **What can you do for a dislocation?** In your study of physiology you have learned that there are several kinds of joints in the body, and that the ends of the bones which form such joints are tied together by strong ligaments. A sudden wrench upon a bone may tear some of the ligaments enough to permit the bones to be pulled out of place and separated from one another. Such an injury is called a *dislocation.* For example, the head of the upper arm bone may be pulled out of the socket formed by the bones of the shoulder. In such a serious dislocation as that of the shoulder or the hip, for example, a doctor should be called at once to replace the ends of the bones in their proper positions. But while waiting for the doctor to arrive, you may help by keeping the patient as comfortable as possible, and by applying cold compresses to the joint to prevent undue swelling, and to help relieve the pain.

If the dislocation is a minor one, such as a toe joint or a finger joint, you may be able to reduce the dislocation by holding the finger or toe very firmly with both hands while you pull it forward in a straight line until the bone slips back into place. Even in such cases, it is advisable to call a physician.

429. **What is the proper thing to do for a sprain?** It is possible, of course, to suffer a sprain of almost any joint, but a sprained wrist or a sprained ankle is the most common type of sprain. One steps sidewise on his foot and turns or twists his ankle. A sprain or a dislocation may occur. If it is merely a sprain, the bones immediately snap back into their normal positions after a temporary dislocation. The ligaments may be stretched unduly or torn slightly. If the sprain is a severe one, the victim must not use the injured joint until it has been bandaged.

If the sprain is serious, you can do two things before the doctor arrives: (*a*) keep the sprained joint in an elevated position to prevent an excess of blood from flowing to it; (*b*) apply cold compresses to the injured part, or pack it with bags filled with ice.

430. How does a strain differ from a sprain? A sprain is an injury to the joint and its ligaments. A strain is an injury to a muscle or a tendon. It is caused by overexertion. A strain varies in severity, sometimes resulting in an excessive stretching of the muscles, and in more severe cases in the tearing of some of the muscle fibers.

A pulled muscle or tendon must have rest. Heat applications may help to remove the pain. Gentle rubbing helps to stimulate the circulation and get rid of an excessive amount of lymph. It is doubtful whether the use of a liniment is of much value, but it does ensure a certain amount of massage. Such massage should be toward the heart to aid circulation in the veins.

431. What are two kinds of fractures? Bones are often broken as a result of a fall or some other injury. In a *simple* fracture, the skin is not broken or punctured. In a *compound* fracture, the skin is broken at the surface, and muscles and other tissues are also torn by the sharp ends of the broken bone. In a compound fracture, there is the danger from the bone injury and also the danger of infection.

In the case of a broken leg, the patient should not be moved until the doctor arrives. Support the limb on a soft pillow or coat. You may help to keep him comfortable. Keep him warm and, if necessary, give him a stimulant, such as beef tea or coffee. Alcohol is not a stimulant. If bleeding is excessive from a compound fracture, you may use pressure to check the excessive loss of blood. Clothing may be ripped at the seams or cut away in order to get at the injured part and prevent loss of blood. No victim of a broken-bone accident should ever be moved to a doctor or a hospital until splints and bandages have been used to keep the

injured bones and muscles from all irritation. Anything stiff and flat can be used for splints, such as a cane or an umbrella, heavy cardboard, rolled-up blankets or clothing.

432. What are common causes of suffocation? There are several ways in which the supply of oxygen may be cut off from the body. When that happens, breathing stops and suffocation occurs. The person soon becomes unconscious, and death will occur in a short time unless first aid is at hand. The treatment in all cases is almost exactly the same, *the use of artificial respiration.* Let us mention some of the common causes of suffocation.

a) *From poisonous or choking gases.* The poisonous gas which causes most cases of asphyxia is *carbon monoxide.* This gas is given off from the exhaust of automobile engines; it escapes from leaky gas jets; it is given off when charcoal burns; and it escapes from furnaces which are improperly cared for, or from leaky stovepipes and chimneys. As small an amount as 1 part in 500 parts of air will cause unconsciousness in a half hour. [See Fig. 19–7.]

FIG. 19–7. Anyone who works around an automobile when the engine is running is in danger of suffocation and poisoning from carbon monoxide. The gas has no odor to warn the person who is breathing it. (*Gustav Anderson from Ewing Galloway*)

Other gases which will cause suffocation are carbon dioxide, gasoline vapor, ether vapor, and the vapor from carbon tetrachloride. In fact, almost all the liquids used for dry cleaning give off vapors that are suffocating.

b) *From electric shock.* If a person comes into contact with a " live " wire, he may be rendered unconscious from the shock. Usually the nerves which control breathing are partially paralyzed. If the person grasps the wire, he cannot let go because his muscles have contracted. It is difficult to release him and dangerous to do so, unless you use a long dry stick, dry clothing, preferably of silk, rubber gloves, or some other nonconductor of electricity to pull him away or to remove the wire.

c) *Drowning.* If a person is submerged in water, of course no more oxygen can get into his lungs. He soon becomes unconscious. The reserve, or supplemental, air in the lungs does continue to supply him with some oxygen for a short time. He may live five minutes only, but there are cases on record where a person who had been in water for a half hour was revived by artificial respiration.

433. How is artificial respiration carried out? The *prone-pressure* method of artificial respiration is usually called the Schäfer method, because it was first advanced by Sir Edward S. Schäfer. Because it is efficient and safe (unless the person using it is too rough), the Schäfer method is the standard method used by many large corporations, by United States Bureaus, and by the Red Cross. The technique of this method is as follows:

a) Turn the patient over so that he lies on his stomach, with one arm extended above his head and the other arm bent at right angles at the elbow. The face rests on the forearm, and it is turned sidewise so the mouth and nose are not obstructed. [See Fig. 19–8A.]

b) You then kneel astride the patient's thighs in the position shown in the figure. Next you place the palms of your hands on the patient's back with your fingers resting on his

ribs, in such manner that the little finger touches his lowest rib. [See Fig. 19–8B.]

c) With your arms held straight, you then swing your body forward slowly until your shoulder is directly above your hands, as shown in Figure 19–8C. The weight of your body thus causes pressure upon the patient's body. This part of the operation should take about two or three seconds.

d) To relieve the pressure, you then swing backward and pause for about two seconds. In such manner you complete in four or five seconds a double movement of pressure and release, corresponding to natural respiration.

e) After two seconds you swing forward again. You continue to repeat these operations at the rate of about twelve to fifteen times per minute until the patient begins to breathe naturally. If one repeats, at normal rate of speech, " Out goes the bad air " while compressing the sides; then " In comes the good " when releasing the hands, this helps to time the procedure correctly. You must not stop until the patient revives or until a physician declares that the patient is no longer living.

A B

C

Fig. 19–8. Artificial respiration. A shows the first position; B, the placement of the hands; C, the use of pressure. (*Courtesy U. S. Bureau of Mines*)

Persons have been revived by artificial respiration after from two to four hours of *resuscitation* (rē·sŭs′ĭ·tā′shŭn).

f) When the patient begins to breathe naturally, the clothing about his neck, chest, and waist is loosened. He must be kept warm, however, as cold and chill at such time open the door for pneumonia to follow.

434. What precautions must one take after artificial respiration? The patient must be kept quiet for some time. No liquid should be given until he is fully conscious. Then he may be given such a stimulant as hot coffee or aromatic spirits of ammonia. Be ready to resume the work of artificial respiration if the patient should suddenly stop breathing again. If it is necessary to change operators, each one should use the same timing and rhythm. If there is water in the lungs, most of it at least will be removed by the use of the Schäfer method of artificial respiration.

Since carbon monoxide unites with the red blood cells and makes them unable to carry oxygen, a victim of carbon-monoxide poisoning needs some stimulation after artificial respiration. *Carbogen* (kär′bō·jĕn) is often administered by means of an *inhalator* (ĭn′hȧ·lā′tẽr), or apparatus for making it easy to breathe in some gas. It consists of a mixture of from 5 per cent to 10 per cent carbon dioxide with oxygen. The carbon dioxide stimulates the respiratory center, and the oxygen helps to drive the carbon monoxide from the blood and to supply the tissues with the needed oxygen.

435. What are the symptoms of poisoning? Sudden illness is the most common symptom of poisoning. Most diseases develop gradually. Suppose that a friend of yours has been feeling well, has a good appetite, and seems to be in excellent health. An hour or so after he has drunk some liquid or eaten some food, he is taken violently ill. He may be pale or flushed. He may have *convulsions* or he may sink into a *coma*. Possibly violent vomiting occurs. In such cases, you may suspect that he has partaken of something which is poisonous.

436. What can you do if the poison is unknown? The following general procedure may be helpful in cases of suspected poisoning, and it can hardly do any harm:

a) Telephone at once for a doctor.

b) Induce vomiting. If poison has been taken into the stomach, some of it may be removed by vomiting. You may tickle the patient's throat with a finger or with a feather. You may give him warm salt water or warm water in which baking soda or mustard has been dissolved. Even dishwater may be given to cause vomiting. The drug known as *ipecac* (ĭp′ė·kăk) contains *emetine* (ĕm′ė·tēn), which is one of the best *emetics* (ė·mĕt′ĭkz) known. If ipecac is available, it may cause vomiting when other things fail to do so.

c) Give the patient milk or white of egg. These protein foods unite chemically with many different poisons and form insoluble substances which are not absorbed by the digestive tract. In such manner, any poisonous substance left in the stomach is destroyed.

d) Give the patient a *purgative* (pûr′gȧ·tĭv) to remove the poison from the intestines. There are a few cases where a purgative should not be given. If the sudden illness is the result of an acute attack of appendicitis, then no purgative should be given. Castor oil is safe in most other cases, but it should not be given for phosphorus poisoning. Epsom salts may be used as a purgative.

e) Put the patient to bed and keep him warm, and as comfortable as possible.

437. What are some common poisons? Such strong acids as nitric, hydrochloric, and sulfuric not only are poisonous, but they eat away the flesh.

Common lye contains sodium hydroxide. It is poisonous and it *corrodes,* or eats away. Potassium hydroxide and ammonium hydroxide (aqua ammonia) are also poisonous. Calcium hydroxide is corrosive to the flesh. Its common name is *slaked lime.* These compounds are all examples of bases or *alkalis.* They are particularly dangerous to the eye.

Nearly all the alcohols, including grain alcohol, are poisonous. A druggist places the skull and crossbones poison label on a bottle of wood alcohol. Since grain alcohol has been found to be just as poisonous, one wonders why the poison label is not used on bottles containing that particular alcohol. Carbolic acid is a very poisonous alcohol.

Gasoline and kerosene are poisonous. They should be kept away from children to avoid all danger that the children might try to drink them.

Tincture of iodine is poisonous. In fact, nearly all disinfectants and some antiseptics are poisonous.

Such narcotics as opium and morphine are poisonous.

Some cough medicines contain the deadly poisonous prussic acid which the chemist calls hydrocyanic (hī′drō-sī·an′ĭk) acid. Potassium cyanide, which is sometimes used for cleaning silverware, is a deadly poison. Even its vapor kills quickly.

Phosphorus is a poison. It has been used in some poisons for vermin.

The soluble salts or compounds of nearly all the heavy metals are poisonous. This list includes the soluble compounds of arsenic, lead, mercury, copper, zinc, tin, and silver.

438. What can you do if the poison is known? It is possible to give an *antidote*, which is a substance which unites with the poison itself, either making it insoluble or neutralizing its effects. For reference, the following list of antidotes is given.

a) *Acids.* Baking soda, chalk, or milk of magnesia.

b) *Alkalis.* Vinegar, lemon juice, or orange juice.

c) *Alcohol.* Strong coffee.

d) *Iodine.* Starch paste, or starchy foods in quantity.

e) *Narcotics and opiates.* Strong black coffee.

f) *Hydrocyanic acid and cyanides.* The action of these chemicals is so rapid that little time is offered for treatment. Inhaling ammonia and the use of artificial respiration may be helpful.

g) *Phosphorus.* Tiny crystals of copper sulfate; Epsom salts. It takes so long before the patient feels the effects of phosphorus poisoning that there is little advantage in giving an antidote.

h) *Arsenic.* Ferric hydroxide, freshly precipitated (separated as a solid from a solution); even iron rust ground up in water; milk.

i) *Lead.* Epsom salts; white of eggs; milk.

j) *Silver salts.* Common table salt.

k) *Salts of copper, tin, mercury, and zinc.* Milk, white of eggs.

l) *Carbolic acid.* Grain alcohol, raw eggs, or Epsom salts.

439. Some hints and cautions. Some of the following suggestions may add to your comfort or help to lengthen your life:

a) Do not keep disinfectants and other poisons in the medicine cabinet. It is true that many medicines are poisonous, too, but they may not be so poisonous in small doses.

b) Do not leave the iodine bottle unstoppered. In fact, it is a poor policy to leave any medicine bottle unstoppered.

c) Do not take medicine from unlabeled bottles. Sometimes the label comes loose and falls off. If the label is lost, it is safer to throw the medicine away.

d) Do not go to the medicine cabinet and take medicine from any bottle, unless you turn on the light to see what you are getting. Some other person may have moved the bottle.

e) Do not use calomel tablets which have been long exposed to the light. Such exposure changes the calomel to the deadly bichloride of mercury.

f) Do not take larger doses of any medicine than those prescribed.

g) Do not take any medicine mailed to you or thrown on your doorstep as a sample.

h) Be extremely cautious about taking so-called antipain pills or powders.

Questions

1. Explain how you would prepare a tourniquet and tell how you would use it. What precautions would you take in the use of a tourniquet?

2. Why are puncture wounds likely to be dangerous? What is the best treatment for such injuries?

3. How big a scratch or pin prick does it take to make a hole large enough for bacteria to enter?

4. What first-aid treatment would you use for a first degree burn?

5. What would you do to prevent a sunburn? How would you treat a sunburn?

6. Why is vigorous rubbing of a frost-bitten ear with snow not good first-aid treatment?

7. Why may the bite of a dog or a cat be dangerous? What first-aid treatment would you use for dog bite?

8. What is meant by milking a rattlesnake? What is antivenin?

9. While your teacher is out of the room, one of your classmates faints. What would you do?

10. How does a sprain differ from a strain? What is the proper first-aid treatment for each one?

11. Why should you avoid moving a person who has suffered a broken bone? If you cannot get a doctor and it is necessary to move a person who has a broken arm or leg, what precautions would you take?

12. What are the symptoms of poisoning?

Some things for you to do

1. Demonstrate the Schäfer method of using artificial respiration. How long should the treatment be continued?

2. Find out the difference between the term *antiseptic* and the term *disinfectant.*

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Glossary

ACOUSTIC (*ȧ*·kōōs′tĭk), pertaining to the science of sounds.

ADENOIDS, growths on the upper wall of the throat at the rear of the nasal cavity.

ADRENAL (ăd·rē′n*ă*l) GLAND, one of a pair of ductless glands, which are attached to the kidneys. They secrete adrenaline (*ă*d·rĕn′*ă*l·ĭn).

AERATION (ā′ẽr·ā′sh*ŭ*n), the process of exposing to the action of the air; supplying or charging with air.

AFTER-IMAGE, the memory or mental picture which lasts for a moment after we see something. It is this after-image which makes persons see motion pictures as moving pictures, rather than as a series of still pictures.

AIR CONDITIONING, planned changes in the qualities and characteristics of air before it enters a building or a room. The changes include purifying, humidifying or dehumidifying, and warming or cooling the air.

ALGAE (ăl′jē), plural, one type of flowerless plant.

ALIMENTARY CANAL, in animals, the tube in which food is digested.

ALKALI (ăl′k*ȧ*·lī), a substance whose properties are opposite to those of an acid.

ALLERGIC (*ă*·lûr′jĭk), sensitive to foreign substances.

ALTIMETER (ăl·tĭm′ė·tẽr), an aneroid barometer graduated to read altitude in feet.

ALVEOLUS (ăl·vē′ȯ·l*ŭ*s), an air sac of a lung.

AMOEBA (*ȧ*·mē′b*ȧ*) plural AMOEBAE (*ȧ*·mē′bē), one of the simplest known animals, consisting of only one cell.

AMPLIFY, of a sound, to increase; to augment; to intensify.

ANAEROBIC (ăn·ā′ẽr·o′bĭk), able to live without free oxygen.

ANTHRAX, an infectious and usually fatal disease, especially of animals.

ANTICYCLONE, a wind movement or atmospheric condition, usually associated with clear weather, in which the barometer readings are high.

ANTIDOTE, a remedy which may be used as a preventive.

ANTISEPTIC, anything that destroys or restrains the growth of bacteria and some other microorganisms.

ANTITOXIN, a substance produced in the blood, which tends to neutralize the toxin, or poison, of bacteria.

ANTITRADES, the prevailing westerly winds of middle latitudes.

ANTIVENIN, a serum used as an antidote for snake bites.

ANUS (ā′nŭs), the opening of the alimentary canal, through which food refuses are excreted.

AORTA (ȧ·ôr′tȧ), the largest artery in the body.

APPENDAGE (ă·pĕn′dĭj), an external organ or limb.

AQUEDUCT (ăk′wė·dŭkt), a channel or pipe for conveying water.

AQUEOUS (ā′kwė·ŭs), watery.

ARTERY, a blood vessel carrying blood away from the heart.

ARTESIAN (är·tē′zhăn) WELL, a well bored deep enough to reach water that will gush up through it like a fountain. It is named for the province of Artois in France, where it was first popular.

ASSIMILATION (ă·sĭm′ĭ·lā′shŭn), the changing of food into the protoplasm of cells.

ASTIGMATISM (ȧ·stĭg′mȧ·tĭz'm), a condition of faulty curvature of the lens of the eye, so that some of the rays of light do not properly focus on the retina.

ASTRINGENT (ăs·trĭn′jĕnt), a drug that puckers the mucous membrane. It tends to cause constipation.

AURICLE (ô′rĭ·k'l), one of the two upper chambers of the heart; the projecting part of the external ear.

AUTONOMIC (ô′tō·nŏm′ĭk) NERVOUS SYSTEM, a part of the nervous system which regulates involuntary responses from the organs of the chest and abdomen, especially those concerned with circulation, digestion, and reproduction; the sympathetic nervous system.

AXON (ăk′sŏn), a fibrous extension of a nerve cell, through which impulses leave the cell body.

BACILLUS (bȧ·sĭl′ŭs), plural BACILLI (bȧ·sĭl′ī), any individual of a large group of rod-shaped bacteria.

BACTERIUM, plural BACTERIA, a single cell of certain one-celled flowerless plants.

BAROMETER (bȧ·rŏm′ė·tẽr), an instrument used to measure air pressure. An aneroid (ăn′ẽr·oid) barometer is one which contains no liquid and is used chiefly by aviators. A mercurial barometer is one containing mercury and is in general use.

BAST, a strong woody fiber found in the inner bark of the stem of many plants.

BEL, the unit used for measuring loudness; named after Alexander Bell.

BICEPS (bī′sĕps), the flexor muscle of the upper arm.

BILE, a yellowish liquid produced in the liver and passed off into the intestine from the gall bladder. It aids in digestion.

BIOCHEMIST, a person well versed in the knowledge of the chemical structure and chemical actions of living things.

BLADDER, a membranous sac in animals for the temporary retention of urine.

BLOOD, the fluid which circulates throughout the body, carrying oxygen and food to the cells and removing waste products from the cells.

BLOOD CLOT, the solid matter formed by certain liquid parts of the blood.

BLOOD VESSEL, in the body of an animal, any tube which carries blood.

BOLL (bōl), the fruit of the cotton plant.

BONE, one of the parts of the skeleton of an animal, formed chiefly of calcium compounds.

BRAIN, the center of the nervous system in most animals.

BRAWN, the muscles of an animal.

BRITISH THERMAL UNIT, the amount of heat needed to warm one pound of water one degree Fahrenheit.

BRONCHIAL (brŏng′kĭ·ăl) TUBES, any of the bronchi, or windpipes, and their branches.

BRONCHIOLE (brŏng′kĭ·ōl), one of the small bronchial tubes.

BRONCHUS (brŏng′kŭs), plural BRONCHI (brŏng′kī), one of the two main branches of the trachea, leading into a lung.

CAFFEINE (kăf′ē·ĭn), a bitter and stimulating alkaloid substance found chiefly in the leaves and berries of the coffee plant, also in tea leaves.

CAISSON (kā′sŭn), a chamber in which there is more than normal atmospheric pressure, used for construction work under water.

CALCIUM, one of the important elements found usually in combination with other elements. It is necessary for the formation of bones and teeth in animals.

CALORIE, the unit used in the metric system to measure heat. A large calorie, or kilocalorie, is the amount of heat used to raise one pound of water 4° Fahrenheit.

CAPILLARY, one of the smallest blood vessels in the body.

CARBOHYDRATES, sugar, starch, and some other compounds; they are used in the body to furnish heat and physical energy.

CARBON, an element found native and as a constituent in many substances.

CARBON DIOXIDE (kär′bŏn dī·ŏk′sīd), a colorless gas, present in the atmosphere. It is one of the sources out of which green plants can make nutrients.

Carbon monoxide, a colorless, poisonous, flammable gas formed by the incomplete combustion of carbon.

Cartilage, a gristle-like tissue. Cartilage cells precede the formation of bone cells.

Cauterize (kô′tẽr·īz), to burn the flesh with a hot instrument or a chemical, as is done in treating the bite of a dog.

Cellulose (sĕl′ṻ·lōs), the woody fiber that forms the walls of plant cells.

Cement, a substance, usually made from limestone and clay, which hardens after being mixed with water.

Centrifuge (sĕn′trĭ·fūj), an instrument used to separate liquids by whirling them at high speed; thus the blood cells can be separated from the plasma.

Cerebellum (sĕr′ê·bĕl′ŭm), the part of the brain between the cerebrum and the medulla; it controls co-ordination of muscular activity.

Cerebrum (sĕr′ė·brŭm), the largest part of the brain. It controls voluntary movement, and, in man and other higher animals, it is concerned with the emotions and thought processes.

Chemical action, any action in which there is a change in the chemical nature of the substance concerned.

Chlorine (klō′rēn), a gas used as an agent in bleaching cotton.

Cilia (sĭl′ĭ·ȧ), microscopic hairlike structures found in the respiratory system of higher animals. Cilia are also possessed by many of the invertebrates.

Circulatory system, the channels by which liquids and gases are moved from one place to another in living things; usually applied to the heart, blood vessels, and blood of an animal.

Cirrus (sĭr′ŭs) cloud, a light, fleecy cloud, occurring at great elevation.

Clockwise, in the same direction in which the hands of a clock move.

Cocaine (kō·kān′), a drug extracted from the leaves of an evergreen shrub grown in South America and in Java.

Coccus (kŏk′ŭs), plural Cocci (kŏk′sī), one individual of a large group of spherical, or ball-shaped, bacteria.

Cochlea (kŏk′lḗ·ȧ), the inner ear.

Coke, the solid material left after heating soft coal.

Colchicine (kŏl′chĭ·sēn), a chemical which causes alterations, including mutations, in plants.

Colon, the large intestine extending from the small intestine to the rectum.

Complementary color, one of a pair of contrasting colors. Red is complementary to green.

CONCAVE (kŏn′kāv), hollowed; shaped like the inside wall of a hollow sphere.

CONCUSSION, a severe blow, or the condition resulting from such an impact.

CONDENSATION (kŏn′dĕn·sā′shŭn), the process in which a vapor (usually water vapor) is changed into a liquid, because its temperature has been lowered.

CONDENSITE (kŏn·dĕn′sīt), an artificial plastic made from carbolic acid and formaldehyde.

CONDUCTION, that method of transferring heat in which the heat passes from molecule to molecule.

CONE, a special nerve cell in the retina of the eye.

CONTAMINATED, soiled or stained; defiled or polluted.

CONTINENTAL CLIMATE, a climate which is subject to extremes of temperature.

CONVECTION, a method of transferring heat by the intermingling of heated masses of air.

CONVEX (kŏn′vĕks), rounded; shaped like the outside surface of a sphere.

CORNEA (kôr′nē·ȧ), the transparent part of the coat of the eyeball; it covers the iris and the pupil.

CORPUSCLE (kôr′pŭs·'l), a blood cell.

CORRODE, to wear away, or make smaller; to rust or tarnish.

CORTEX, in the brain, the thin outer layer of brain cells, called the gray matter.

CURRENT, a moving stream of water.

CYCLONE (sī′klōn), a large storm in which the barometer readings are relatively low.

CYTOPLASM (sī′tô·plăz'm), the protoplasm between the nucleus and the membrane of a cell.

DAMPER, a valve or movable plate in the front of a stove or furnace, or installed in the exit pipe.

DECIBEL, one of the smaller units used for measuring loudness. Named after Alexander Bell.

DECOMPOSED (dē′kŏm·pōzd′), separated into the elements of which it is made up; decayed.

DENDRITE (dĕn′drīt), a fibrous extension of a nerve cell, through which impulses enter the cell body.

DERMIS, the inner layer of skin under the epidermis; in it are found blood vessels, nerves, the base of sweat glands, and the roots of hairs.

DEW POINT, the temperature at which a vapor begins to be deposited as a liquid.

DIAMETER, a straight line through the center of a circle or of a rounded object.

DIAPHRAGM (dī′ȧ·frăm), a muscular wall in mammals, separating the chest cavity from the abdominal cavity; a vibrating membrane, or disc, as in the phonograph.

DIGESTION, the chemical change involved in the breaking down of food so that it can be used by the body.

DISINFECTANT, something which destroys the cause of infection; usually a chemical which destroys harmful microorganisms.

DISTILLATION, the changing of a liquid or a solid to a vapor, and the condensing of the vapor to a liquid or a solid.

DOLDRUMS (dŏl′drŭmz), a calm belt near the equator, where air currents are rising.

DORSAL, situated on, or near, the back. The dorsal region of animals is usually uppermost.

DRIFT, in the ocean, a movement slower than a current.

DRY ICE, solidified carbon dioxide used as a substitute for ice or as a refrigerant.

DUCT, a tube or vessel.

DUCTLESS GLAND, in the body of an animal, an organ which has no duct, or opening, but which passes off its secretions, or hormones, in the blood by absorption.

EARDRUM, the membranous partition at the inner end of the outer canal of the ear; it separates the middle ear from the outer ear.

EAR LOBE, the external flap, or projection of membrane, below the ear.

ECTODERM (ĕk′tô·dûrm), the outer body layer of certain low vertebrates; the outer layer of an animal embryo.

ELIMINATE, to pass off, as water by transpiration from plants, and various wastes by excretion from animals.

EMBRYO, a very young animal, before it is hatched or born; the term also applies to the young plant in the seed.

EMETIC (ė·mĕt′ĭk), an agent which causes vomiting.

ENDODERM (ĕn′dô·dûrm), the inner body layer of certain low vertebrates; the inner layer of an animal embryo.

ENVIRONMENT, all the surrounding conditions or outside influences that affect the life of the individual.

ENZYME (ĕn′zīm), a substance that causes chemical change without itself being altered.

EPIDEMIC (ĕp′ĭ·dĕm′ĭk), applied to a disease which spreads widely and attacks many persons in the same locality.

EPIDERMIS, the outer layer of the skin.

EPITHELIAL (ĕp′ĭ·thē′lĭ·ăl) CELL, a skin cell.

ETHANOL (ĕth′ȧ·nōl), grain alcohol.

EUSTACHIAN (ū·stā′kĭ·ăn) TUBE, the tube which connects the middle ear with the throat.

EXHALATION, the forcing of air out of the lungs.

EXOSKELETON (ĕk′sō·skĕl′ē·tŭn), the hardened covering over the bodies of certain invertebrates, such as the lobster, crab, and beetle.

EXTENSOR MUSCLE, a muscle that extends an appendage from the body. The extensor muscle in the upper arm is called the triceps.

FEHLING (fā′lĭng) TEST, a test for the presence of sugar.

FERMENTATION, chemical decomposition of organic compounds, either by living organisms such as yeast, or by chemical substances capable of causing fermentation.

FIBRIN (fī′brĭn), the solid material formed by fibrinogen in clotting.

FIBRINOGEN (fī·brĭn′ō·jĕn), the liquid substance in the blood which, upon exposure to the air, produces a clot.

FISSION (fĭsh′ŭn), reproduction of a cell by splitting into two parts.

FLEXOR MUSCLE, a muscle which bends an appendage. The flexor muscle in the upper arm is called the biceps.

FLUORINE (flōō′ō·rēn), a gaseous element.

FOCAL DISTANCE, the distance of the focus from the surface of a lens or mirror.

FOCAL POINT, the place where rays of light focus after passing through a lens.

FONTANEL (fŏn′tȧ·nĕl′), a temporary space between certain bones of the skull before the bones join.

FORCE PUMP, a pump having a solid piston, or plunger, for forcing a liquid through the valves.

FULLER'S EARTH, a white or brown powdery substance used by tailors in taking spots out of fabrics.

FUSE (noun), in electricity, a strip of easily melted metal inserted in an electric current. It acts as a safety device.

FUSE (verb), to liquefy by heat.

GANGLIA (găng′glĭ·ȧ), plural, GANGLION (găng′glĭ·ŭn), singular, knots of nerve tissue found along the spinal cord and elsewhere in the bodies of most animals possessing a nervous system.

GASTRIC JUICE, a digestive fluid secreted by glands in the walls of the stomach.

GERMICIDE (jûr′mĭ·sīd), a substance which kills bacteria and germs.

GILLS (gĭlz), thin-walled organs, possessed by most aquatic animals, by means of which oxygen is taken into the body of the animal from the water, and carbon dioxide is passed off into the water.

GLAND, a structure or organ more or less hollow, which is useful to the body because of its secretion.

GLOTTIS, the opening or entrance to the windpipe, situated just below the visible throat.

GLYCOGEN (glī'kȯ·jĕn), a sweet substance stored in the liver. It is formed from starch and sugar and is given out to the blood from the liver.

GRAVITY, the force by which each body in the universe is attracted to every other body in the universe.

GULF STREAM, the vast warm current of the North Atlantic Ocean.

GULLET, the food tube extending from the throat to the stomach.

HEART, the organ which pumps the blood and causes it to circulate through the body of an animal.

HEAT EXCHANGE, the transfer of heat from one object to another.

HEMOGLOBIN (hē'mȯ·glō'bĭn), an iron compound contained in the red blood cells.

HEMORRHAGE (hĕm'ŏ·rĭj), bleeding.

HORMONE (hôr'mōn), the essential secretion of one of the ductless glands.

HUMIDITY, the moisture or water vapor present in the air. Absolute humidity is the amount of moisture which the air contains. Relative humidity is the ratio between the absolute humidity and the moisture necessary to saturate the air under given conditions.

HURRICANE, a tornado of large extent, usually found in the tropics but sometimes appearing in temperate zones.

HYDROCHLORIC (hī'drȯ·klō'rĭk) ACID, a colorless, gaseous compound of hydrogen and chlorine that readily dissolves in water to form the substance known as muriatic acid.

HYDROGEN, a gas; the lightest substance known.

HYDROPHOBIA (hī'drȯ·fō'bĭ·ȧ), a disease produced by virus transmitted from the saliva (usually through a bite) of a "mad" dog or other animal suffering from rabies.

IMMUNITY, freedom from; power of resisting a disease.

IMPULSE, nerve activity set up by a stimulus.

INHALATION, the taking of air into the lungs.

INHIBIT, to restrain or prevent.

INOCULATION, planned injection of something, such as antitoxin, under the skin, usually with the purpose of counteracting disease.

INSULATOR, a nonconductor, or something that prevents free passage of electricity from one object to another.

INTESTINE (ĭn·tĕs′tĭn), the tubular part of the alimentary canal, extending from the stomach to the anus.

INVERTEBRATE, an animal having no vertebrae or backbones; sometimes referred to as one of the lower animals.

INVOLUNTARY MUSCLE, a muscle which is not under the control of the will, such as the heart muscles and muscles in the wall of the alimentary canal.

IRIS, in the eye, the muscular, colored curtain surrounding the pupil.

ISOBAR (ī′sȯ·bär), a line drawn through places which have the same atmospheric pressure.

ISOTHERM (ī′sȯ·thûrm), a line drawn through places which have the same temperature.

KIDNEY, one of the two glandular organs which take urea and water out of the blood and pass them off as urine into the bladder.

KILOWATT-HOUR, a unit of work or energy equal to that done by one kilowatt of electricity during one hour.

LAMPBLACK, a fine soot deposited from the smoke of oil, tar, and other substances.

LANOLIN (lăn′ȯ·lĭn), the grease or oil obtained from wool.

LARVA (lär′vȧ), plural LARVAE (lär′vē), the second stage in the life of an insect having four stages in development. The larva stage is between the egg and the pupa stage.

LARYNX (lăr′ĭngks), the organ in the throat containing the vocal cords, by means of which the voice is produced.

LATEX (lā′tĕks), the milky sap of the rubber tree.

LENS, in the eye of higher animals, the transparent disc, by means of which images are formed on the retina.

LEVER (lē′vẽr), a bar which may move freely about a fixed point, or fulcrum.

LIFT PUMP, a pump that lifts water or other liquid from one level to a higher one, by means of a partial vacuum created in its tube.

LIGAMENT, a band of connective tissue connecting two bones at a joint.

LIVER, the largest organ in the body of vertebrates, situated in the upper part of the abdominal cavity.

LUNG, a breathing organ, usually found in pairs in air-breathing vertebrates.

LYMPH (lĭmf), the colorless fluid that surrounds the cells of the body.

LYMPH NODE, one of the small lumps in the lymphatic system, found in various parts of the body. The lymph nodes contain numerous white blood cells.

Lymphatic system, the tubes extending all over a person's body, carrying the lymph.

Magnesium, a light, silver-white metallic element. It is important as an essential substance in our food.

Manganese, a hard, grayish-white metallic element.

Marrow, the soft, greasy substance found in the central cavity of long bones.

Medium, plural Media (mē′dĭ·ȧ), that which lies between things, or in the middle; a substance through which a force acts or an effect is obtained.

Medulla (mė·dŭl′ȧ), the lowest part of the brain.

Mesoderm (mĕs′ô·dûrm), the middle germ layer of the embryo.

Molecule (mŏl′ĕ·kūl), the smallest particle into which matter can be divided without losing its identity.

Monsoon, a huge seasonal land and sea breeze.

Morphine, a narcotic drug made from opium, and used to alleviate pain.

Motor nerve, a nerve carrying an impulse to a muscle or a gland.

Mucous membrane, the skin lining the mouth, nostrils, throat, and other parts of the digestive and respiratory systems.

Mucus, the secretion of the mucous membrane.

Muscle, a tissue found in all animals, except the lowest; its contractions produce motion and locomotion.

Mutant (mū′tănt), a striking change in a plant or an animal, which is passed on to the new generation.

Mutation, a striking characteristic in which an offspring differs from its parents.

Narcotic, any substance which deadens the nerves and makes them respond less readily. Alcohol, opium, and morphine are examples of narcotics.

Nerves, whitish cords made up of nerve fibers, by means of which nerve impulses or messages are carried between the various body parts.

Neuron (nū′rŏn), a nerve cell.

Neurosis (nū·rō′sĭs), a breakdown, often temporary, of the nervous system, producing bad mental conditions.

Nicotine (nĭk′ō·tēn), a colorless, oily alkaloid substance found principally in the leaves of the tobacco plant. It is a very poisonous substance.

Nitrogen, the gas comprising 78 per cent of the atmosphere.

Nonconductor, a substance that does not transmit heat or electricity.

NUCLEUS (nū'klē·ŭs), the most important part of a cell, frequently ball-like in shape.

NUTRIENT, any substance which furnishes nourishment for the promotion of growth or the repair of tissue, or which furnishes fuel for oxidation in the body.

NYLON (nī'lŏn), a man-made substance, produced from coal, water, and air, and spun into a thread. It can be made strong enough to be used as bristles or fine enough to be used as a substitute for silk.

OCEANIC (ō'shē·ăn'ĭk) CLIMATE, a climate which is not subject to extremes of temperature.

OLFACTORY CELLS, elongated sensitive cells located in the mucous membrane in the upper part of the nasal cavities. They are the organs of smelling.

OPTICAL ILLUSION, a combination of lines or of figures which produce erroneous beliefs as to their true dimensions and the correct relations of the parts shown.

ORGANIC MATTER, something that has or has had life; applied by chemists to compounds containing the elements hydrogen and carbon.

ORGANISM, the entire body of an individual plant or animal composed of organs or parts performing special functions.

OSMOSIS, the passing of a fluid through a thin wet membrane.

OVERTONES, notes whose pitch is an octave or more higher than that of a given tone.

OVIDUCT (ō'vĭ·dŭkt), in an animal, a tube for carrying eggs to the outside of the body.

OXIDATION (ŏk'sĭ·dā'shŭn), the combining of oxygen with some other substance.

OXIDE, a compound containing oxygen and some other substance.

OXYGEN, the most abundant element on the earth's surface.

OXYHEMOGLOBIN (ŏk'sĭ·hē'mō·glō'bĭn), a chemical combination of oxygen and hemoglobin.

OZONE, a very active form of oxygen.

PANCREAS (păn'krē·ăs), a tongue-shaped digestive organ located between the stomach and the intestine.

PAPILLAE (pȧ·pĭl'ē), minute projections on the surface of the tongue.

PASTEURIZATION, a process of killing bacteria in milk by the use of heat. It is so-called after Louis Pasteur, who invented the process.

PEPSIN, an enzyme, found in the gastric juice of the stomach, which digests protein.

PERIOSTEUM (pĕr'ĭ·ŏs'tē·ŭm), a membrane covering the outside surface of the bone. New bone cells are formed from this membrane.

PERSPIRATION, the watery liquid excreted by the sweat glands of the skin.

PHARYNX (făr′ĭngks), the throat.

PITCH, the highness or the lowness of a tone produced by the rate of vibration of the sound waves.

PITUITARY (pĭ·tū′ĭ·tĕr′ĭ) GLAND, a small ductless gland on the underside of the brain. The hormones secreted by this so-called master gland determine the growth of bones and the size of the body, besides regulating many internal activities.

PLASMA, the nearly colorless, liquid part of the blood.

PLASTIC, a substance which may be softened and then blown, pressed, or molded into any desired shape.

PLEXUS, a junction of nerves found in the sympathetic nervous system.

PORE, a small opening in the skin by means of which perspiration is passed off from the body.

PRECIPITATION (prė·sĭp′ĭ·tā′shŭn), the condensing of water vapor into drops which may fall to the earth as rain, sleet, or snow, or which may form on objects on the earth as dew or frost.

PROTEIN (prō′tė·ĭn), a substance necessary for forming protoplasm.

PROTOPLASM (prō′tō·plăz′m), living matter; the essential life substance making up the cell.

PTYALIN (tī′ȧ·lĭn), an enzyme found in saliva, which enables the saliva to have a chemical and digestive action on starch.

PULMONARY (pŭl′mō·nĕr′ĭ) ARTERY, the artery which carries blood from the heart to the lungs.

PULSE, the wave or throb in the blood of an artery, due to the contraction of the ventricle of the heart.

PUPIL, the opening in the iris through which light enters the eye.

QUADRUPED (kwŏd′rōō·pĕd), a four-legged animal.

QUININE (kwī′nīn), a white crystal obtained from the bark of the cinchona tree; it is used as a medicine, chiefly in the control of malaria.

RABIES (rā′bĭ·ēz), a disease occurring among animals, principally dogs and wolves. It is known also as hydrophobia.

RADIATION, that method of transferring energy by the transmission of energy in the form of waves.

RAYON, an artificial fiber which, when woven, is used as a substitute for silk.

REFLEX (rē′flĕks) ACTION, action in which the spinal cord instead of the brain is the instrument causing the muscular or glandular response.

Residual air, the amount of air constantly in the lungs; usually about a quart and a half.

Respiration, external, the exchange of oxygen and carbon dioxide in the lungs. Internal respiration is the oxidation in the cells by the chemical combination of nutrients with oxygen.

Respiratory system, the breathing system in animals, consisting, in the higher animals, of the two lungs, the windpipe and air passages, and the ribs and diaphragm.

Resuscitation, reviving or restoring to conscious life after breathing has stopped or consciousness has lapsed.

Retina (rĕt′ĭ·nȧ), the membrane of the eye, which receives the image in vision. The retina is connected with the brain by the optic nerve.

Rod, a nerve cell of the retina of the eye; the rods seem to make the retina more sensitive in the dark.

Roof membrane, a delicate membranous structure found above the hair cells, floating in the liquid, in the inner ear.

Saliva (sȧ·lī′vȧ), the fluid which is discharged into the mouth. It aids in tasting, chewing, swallowing, and speaking. It is also of some assistance in digestion.

Salivary (săl′ĭ·vĕr′ĭ) gland, one of the glands which secrete the fluid called saliva.

Sea level, the level of the surface of the sea.

Secretion, a substance which is secreted, or given off, by a cell or cells; its primary source is usually the blood of animals.

Sediment, settlings; dregs; material deposited by water.

Sensory nerve, a nerve carrying an impulse toward the spinal cord or the brain.

Septic, causing or tending to promote decay.

Serum, a liquid substance obtained from the clotted blood of an animal made immune to a certain disease; it is used to cure or to prevent this disease in human beings or in other animals.

Sinus (sī′nŭs), a cavity in the skull bones which connects with the nostril cavity.

Siphon, a tube by means of which a liquid may be transferred by atmospheric pressure from one container to another.

Sodium bicarbonate, a white salt having a slight alkaline taste. It is used medicinally, also in cooking as an ingredient of baking powder.

Solar plexus, a group of nerves located over the stomach in a human being.

Solution, a liquid consisting of a solvent and a solute.

Solvent, a fluid which is capable of dissolving, or helping to dissolve, another substance.

Sound, the mental interpretation of the impulses set up in the ear by vibrations which reach the brain by means of the auditory nerve; that which is heard.

Sperm cell, the male cell, the nucleus of which in fertilization unites with the nucleus of the egg cell.

Spinal nerves, the paired nerves of the spinal cord.

Spinnerets, in insects, organs for producing thread, such as silk; also artificial devices used by man in spinning.

Spirillum (spī·rĭl′ŭm), one individual of a large group of spiral-shaped bacteria.

Spirometer (spī·rŏm′ē·tĕr), an instrument for measuring the breathing capacity of a human lung.

Spleen, the organ in which old red blood cells are destroyed.

Spore, a small cell by means of which certain flowerless plants — molds, for instance — reproduce.

"Sterilamp," an electric lamp that kills bacteria by its ultraviolet rays. It is used in hospitals and elsewhere to sterilize the air.

Sterile, lacking fertility; free from living microorganisms.

Sternum, the breastbone.

Still, an apparatus used for distilling liquids.

Stimulant, any substance which produces a temporary increase in life energy when taken into the body. Tea and coffee are examples of stimulants.

Stomach, an enlargement in the alimentary canal, in which the early digestion of food takes place.

Stratosphere, the portion of the atmosphere above the highest clouds.

Suspension, a liquid containing an undissolved substance.

Suture joint, an immovable junction of two or more bones in the skull.

Sweat glands, glands in the skin which secrete perspiration.

Tannic acid, an acid made from the extract of certain plants, used in tanning leather; tannin.

Tannin, a brownish extract from certain plants, including coffee beans and oak bark; tannic acid.

Taste buds, organs of taste, found on the tongue, in man and in certain other animals.

Temperate Zones, those portions of the globe that lie between the Tropics and the Arctic or Antarctic Circles.

Tendon, a strong band of connective tissue in which the fleshy portion of a muscle terminates.

Theine (thē′ēn), the essential substance found in tea, chemically almost the same as caffeine.

Thermostat (thûr'mō·stăt), a device for automatically regulating temperature.

Thoracic (thō·răs'ĭk) duct, the largest lymphatic vessel in the body, emptying into the circulatory system in the neck.

Thorax (thō'răks), the part of the trunk in higher animals between the neck and the abdomen.

Tidal air, the amount of air (from 20 to 30 cubic inches) that a person normally inhales and exhales at one breath.

Timbre (tĭm'bẽr), the quality of a tone, as distinguished from pitch and intensity.

Tonsil, one of the two rounded organs at the entrance to the throat.

Tornado, a whirling windstorm of great violence.

Torrid Zone, that belt of the earth that lies between the Tropics of Cancer and Capricorn.

Tourniquet (tōōr'nĭ·kĕt), a loose bandage which can be tightened by inserting a stick and then twisting to increase the pressure against the body. It is to be used only when bleeding cannot be stopped by pressure from the hands.

Toxic, poisonous.

Trachea (trā'kē·ȧ), the windpipe.

Trade winds, winds blowing from the Tropics toward the equator.

Triceps (trī'sĕps), the extensor muscle of the upper arm.

Tropic of Cancer, the great circle parallel to the equator on the north.

Tropic of Capricorn, the great circle parallel to the equator on the south.

Typhoon, a tropical cyclone.

Ultraviolet, rays shorter than violet rays. They are invisible to the human eye.

Undertow, the strong pull of the ocean away from the shore as the waves break and retreat.

Urea (ū·rē'ȧ), a nitrogenous waste substance found chiefly in the urine of mammals.

Urine, the urea, dissolved in water, excreted through the bladder.

Valves, flaps or folds in organs such as the heart, or in tubes such as veins or lymph tubes, which allow liquids to pass in only one direction.

Vaporization (vā'pẽr·ĭ·zā'shŭn), the process of changing liquids into a gaseous condition, usually by means of heat.

Veins, the blood vessels which return blood to the heart.

Venom (vĕn'ŭm), the poison of harmful snakes.

Ventral, situated on the side opposite the dorsal; usually on the lower side of an animal.

Ventricle, one of the two lower chambers of the heart.

Vertebra (vûr'tė·bră), plural Vertebrae (vûr'tė·brē), one of the separate bones composing the spine.

Vertebrate (vûr'tė·bråt), one of the higher animals having a spine, or spinal column.

Vestigial (vĕs·tĭj'ĭ·ăl) organ, a remnant of an organ no longer used.

Vitamin (vī'tȧ·mĭn), a substance in certain foods, necessary for health and to prevent specific diseases.

Vitreous (vĭt'rė·ŭs), glassy.

Vocal cords, folds of membrane found in the larynx. Speech and song are produced by their vibration.

Voice box, the larynx.

Voluntary muscle, a muscle partly under the control of the will, such as the muscles of the arm and leg.

Vulcanizing, the process of treating natural rubber by heating it with sulfur to render it pliable.

Warp, the threads extended lengthwise in the loom for weaving.

Water table, the level at which water is found below the earth's surface.

Whorl (hwûrl), as used here, the curving lines found in the skin on the tips of fingers.

Windlass, a device for hauling or lifting.

Windpipe, the tube called the trachea, which connects the throat with the lungs.

Woof, the filling threads which cross the warp in weaving.

X ray, a radiation which penetrates solids better than ordinary light does.

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